Power

DFID

Solar Thermal Electricity for Developing Countries

Full Report on the findings and conclusions of the project and the international workshop

June 1996 to March 1997

ITP 96[illegible]

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IT Power

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Executive Summary

BACKGROUND

A review of current activities and state-of-the-art Solar Thermal Power (STP) technologies was carried out. The status of STP in developing countries was also assessed. The following five case studies from India were then investigated in some detail:

- Mathania project (35 MW_e parabolic trough/hybrid)
- Gual Pahari plant (50kW_e parabolic trough pilot plant)
- Hindustan Brown Boveri development (a trough system taken to prototype stage)
- Indian Institute of Science development (imported parabolic trough technology)
- Solar Power Corporation (parabolic dish development)

An important lesson that can be learnt from these case studies is the importance of including training of operation and maintenance staff in any STP project, as well as ensuring that spares are provided or are readily available in the future.

TECHNOLOGICAL ASSESSMENT

Electricity Supply and Demand Factors

In order to establish the context in which solar thermal power stations will be operating, the characteristics of the electricity generation and transmission system in India were studied. Data was gathered on the following issues:

- Installed capacity;
- Electricity consumption;
- Current and projected Energy deficits;
- Transmission and distribution network;
- Plant load factor.

Utility owned power generating capacity in India has increased at a rate of over 10% per year since 1950. Despite this, there is today a chronic shortage of grid electricity, and a great deal of inefficiency in the electricity system. This is illustrated by the following key statistics for Indian electricity supplies:

- A peak capacity deficit of 16%
- An electrical energy deficit of 7%
- Transmission and distribution losses of 22%
- Generation capacity load factor of 58%

As a result, in the short term, the Indian grid can absorb additional capacity without any particular problems associated with the low capacity factor of STP plants or the timing of STP generation.

The implications for using STP technologies in a stand-alone capacity in remote locations was also investigated. As a case study, some investigation was carried out on possibilities for using STP on one of the Andaman and Nicobar Islands. There are 572 islands in this group, and they are the most remote region of India. Only 38 of the islands are inhabited, and almost all the electricity is generated by 30MW of diesel generator capacity. The diesel has to be transported from mainland India, which adds almost 30% to the cost. In addition, the emissions from the generators are particularly harmful to the flora and fauna of the islands.

These are the types of issues which start to make STP plant a more appropriate generating technology for these remote areas. Parabolic dish systems are particularly appropriate for these applications, as they offer smaller capacities. In order to achieve an acceptable capacity factor, a hybrid system would be required, perhaps with a diesel generator back-up. In this context, the STP plant would be saving diesel fuel costs, and not diesel capacity. However, in these remote areas, even modest savings in diesel fuel may justify the investment.

Electricity Interface Requirements

This task involved a review of the technical nature of the transmission and distribution network operated in India, and an investigation of the requirements and modes of grid connection, both on the generation side and on the network side.

STP technologies utilise many of the same control and synchronising techniques as fossil-fuelled power plant. However, the output from the solar field is less controllable. During cloudy conditions, it is likely that the output from the solar plant would suffer rapid variations, leading to the alternator tripping in and out of grid connection. From a grid management point of view, it is far from ideal to have a generating station which can quite suddenly trip out of the grid with very little prior warning. It is for this reason that energy storage and/or fossil-fuel back is normally incorporated in a STP plant.

In-country manufacturing

Previous investigations have indicated that, for parabolic dish developments, up to 50% of the total cost of a project could be from domestic sources. In general, most of this is expected to be on the infrastructure, civil works and erection (81% of total costs domestic). In terms of supply of machinery and equipment, only about 20% is predicted to come from domestic sources.

A survey was conducted within India to assess the prospects for an increased proportion of the equipment to be manufactured in-country. Most of the conventional power components (turbines, boilers, alternators, cooling systems, pumps etc) are already manufactured in India and can be procured locally.

The more specialist STP components (such as high reflectivity low iron curved glass, specialist absorbers, heat transfer fluids, tracking systems etc.) cannot currently be procured within India. Given appropriate technology transfer and investment, there is no reason why these specialist components could not be manufactured within India. However, the private sector will not make the necessary investments until there is a sustainable and sufficiently large market for these components. Until this time, some imported components will be required

There are certain STP technologies which utilise fewer specialist components. These include systems which do not require curved reflectors[1], solar ponds and solar chimneys.

Operational Economics

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[1] Messrs Solar Power Corporation of Ahmedabad have developed a dish system which utilises flat reflector facets. Messrs Pitti Renewable Energy Systems of Pune are developing a line concentrator system which utilises a Fresnel lens.

A life-cycle costing model was developed. Published data on capital costs of power systems were combined with specific data for India (such as fuel prices, labour rates, land prices and incentives and subsidies available for renewable energy projects).

The technology options compared for decentralised applications were parabolic dish, diesel generators and grid extension (including transmission costs). For centralised, grid-connected applications, the options compared were:

- Parabolic trough
- Central receiver
- Solar Chimney
- Solar Pond
- Natural Gas Combined Cycle

Various configurations of STP hybrid plant were also modelled. The conclusions of this analysis were as follows:

- For certain decentralised applications, solar thermal power generated using parabolic dish technologies would be more economically viable than grid extension

- A capital subsidy of 30% would be required to make solar thermal power generation using parabolic dish technologies in a decentralized application competitive with that from a diesel generator

- In centralized, grid-connected mode, although presently the electricity from any of the solar thermal technologies is costlier than traditional fossil-fuel sources, parabolic trough-natural gas with 25% solar share appears to be the most economically attractive option

There were several limitations with the model and data used for this analysis. Firstly, the data on capital costs was a mixture of real project experience and projected costs. Also, the published data on costs referred to a variety of plant sizes. Despite these limitations, the overall trends indicated by the model and the resulting conclusions are considered to be valid.

Operations and Maintenance

A review of the O&M implications for the various STP technologies was carried out. This includes investigations of:

- ◊ Data from realised projects, with a breakdown of the elements of O&M
- ◊ On-going research and projected O&M costs
- ◊ Employment implications

The O&M requirements of STP plant can represent up to 20% of the life cycle. They can also represent an important source of employment for local personnel. A 80 MW_e parabolic trough plant has been estimated to require about 50 permanent qualified employees, mostly operators, a maintenance group and plant administration.

There is evidence to suggest that previous STP pilot projects in developing countries have not placed sufficient emphasis on the continued successful operation of the plant. Insufficient support, training and spares have been supplied to enable long term operation.

It is essential that O&M requirements are considered at all stages of the development of a STP project This is particularly true for developments involving large proportions of imported technology, rather than components that have been manufactured locally. As a minimum, the development must include the following items:

- Adequate training of local operation and maintenance personnel;
- Design and implementation of an methodical operation and maintenance programme;
- Technical support for O&M personnel;
- Supply of sufficient spares, especially of particularly specialist components, which may have a long delivery time,
- Establishment and implementation of an appropriate warehousing programme for maintaining the stock of spares at the site.

In addition, it is important that there are commitments from the suppliers of components that spares will be available for a certain number of years (preferably at least 20).

It is also important to ensure that the project is financially viable throughout its whole operating phase, and to include adequate insurance and reserves in the financial planning. Otherwise, the situation might arise where it is no longer economic to maintain the plant, and it will fall into disuse.

Site Selection

There are many factors which must be considered when assessing a site for a STP plant. Some of these are technical necessities (such as having stable ground conditions on which to develop the plant). Others are conditions which will ensure that the maximum output is achieved from the STP plant. Generally, they can be spilt into three categories:

- Meteorological conditions
- Local conditions (such as soil stability)
- Infrastructure conditions (such as proximity to water supplies and the electricity transmission network)

Each of these categories has been investigated and, where appropriate, guidelines proposed.

Land Use

An assessment of the land use requirements of the various STP technologies was carried out (Figure EX1) The following is the resultant ranking of land use, from least to greatest:

- Dish-Stirling
- Parabolic Trough
- Central receiver
- Solar Chimney
- Solar pond

The impact of this land use will vary from site to site. Possible impacts include:

- Social (e g. population displacement)
- Environmental (e.g. visual appearance, destruction of areas of importance for nature conservation)
- Economic (e.g use of land that has other economic uses such as agriculture).

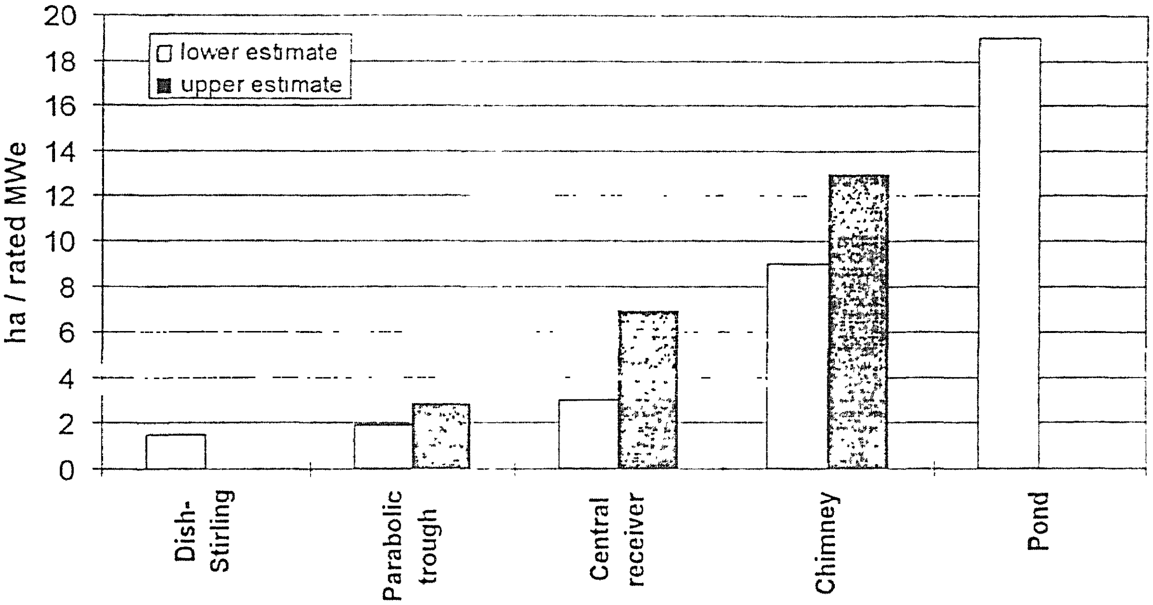

Figure EX1: Land use of various STP technologies

Environmental Impacts

In common with all solar and renewable energies, the main environmental benefits of STP are associated with the reduction in fossil-fuel combustion and associated emissions of:

- Greenhouse gases (mainly carbon dioxide)
- Acidic gases (oxides of nitrogen and sulphur)
- Particulate material

In India, the construction of a STP plant is likely to replace the construction of a coal-fired power station. Coal power stations have the largest emissions of greenhouse gases per unit of electricity generated. Avoiding coal-fired generation is therefore particularly environmentally beneficial. In terms of the greenhouse gas carbon dioxide, the cost of avoiding emissions using a parabolic trough collector could be as low as $50 per ton CO_2.

Given the number of old, inefficient coal-fired power stations being operated in India, the incorporation of STP into a refurbishment programme for these stations would be particularly appropriate. The STP plant could operate in parallel with the refurbished coal boilers, which would provide the back-up. A project of this nature is currently under development in Spain.

An assessment of the environmental impacts of the construction, operation and decommissioning phases of a STP project was carried out. The impacts investigated were emissions to air, water and ground, ecological impacts, noise, visual and water use. The most environmentally hazardous material used is the synthetic heat transfer oil for parabolic trough developments. At operational plants in California, several thousand litres of oil are emitted each year, mostly as a result of gross failure of pipework or fittings. Generally, the oil contaminates a small area of soil, which is removed for decontamination.

It is clear that tight controls and continued monitoring of STP plants is required so that failures of this kind are noticed and repaired quickly Appropriate procedures for spillage control and site remediation should be in place and reviewed regularly.

Safety Issues

A brief risk assessment was carried out on the design and operation of various STP plant. Particular hazards identified include

- Falling glass
- Burns from handling of unguarded hot components
- Overheating of the absorber due to pump failure
- Ruptured pipework emitting heat transfer oils at high temperature
- Faulty control systems leading to a shift of the focus point of a field of heliostats away from the absorber
- The use of sodium filled heat pipes in certain parabolic dish-stirling engine systems
- Structural safety of a very tall solar chimney

Most of the risks associated with STP plant can be minimised by:

- ◊ Careful attention to the design of the system and site
- ◊ Incorporation of fail-safe control mechanisms
- ◊ Implementation of a methodical maintenance and monitoring programme

Decommissioning Factors

Although decommissioning of power plant is not normally considered in India, it is prudent to include some consideration of the decommissioning issues during project development. Many of the issues are common to all power developments, such as the dismantling and removal of large quantities of steel and concrete. Others are unique to STP developments, such as the removal of the large quantities of glass and possibly heat transfer oils at the site

INSTITUTIONAL ASSESSMENT

The key question that this assessment was looking to answer was "What form will future STP projects in developing countries take?" Due to the lack of any existing benchmark pilot projects, the answers to this question were extrapolated from experiences with other technologies in the power sector Background material collected included:

- Information on the existing and future electricity institutional structure in India
- Information on the existing and future rural electrification institutional structure in India
- Information on Independent Power Project structures in general, and in India specifically
- Opinions from key institutional players in India (collected via a series of face-to-face meetings)
- On-going or proposed development strategies by international organisations (such as the EC and World Bank / GEF)
- Market development predictions
- Information on the development of other renewable energy technologies in India

From this information, a picture was first compiled of how STP is likely to develop in India, and in developing countries in general (Figure EX2).

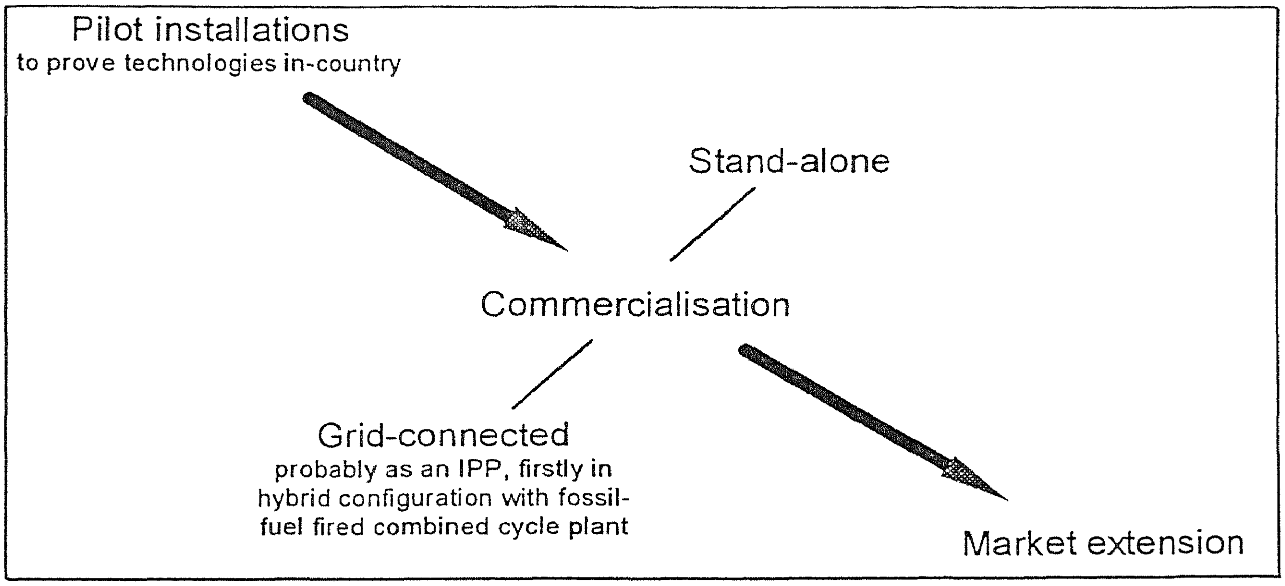
Pilot installations
to prove technologies in-country
Stand-alone
Commercialisation
Grid-connected
probably as an IPP, firstly in hybrid configuration with fossil-fuel fired combined cycle plant
Market extension

Figure EX2: Market Development Scenario

On the basis of this scenario and the other information collected, it was possible to identify the likely role of the key institutional players in this future market (Table EX1).

Other key findings from this assessment (mostly from the survey) include:

- There is currently no official Indian government policy with regard to the development of STP, although there have been activities in this field (most notably, the planned 35 MW_e plant planned at Mathania)
- Renewable energy incentives which would apply to STP projects include 100% depreciation in first year; no sales tax, and no excise duties
- The main barriers to STP developments are the costs, the low capacity factor and the lack of finance for pilot projects
- In the medium term, it was generally accepted that STP projects would be realised on a IPP basis, although there was some uncertainly that this is the best way to handle pilot projects
- There was some concern that the mistakes of past projects would be repeated, and that there would be insufficient in-country manufacture, spares and training.

Table EX1: Role of institutions in STP development

	ROLE
GOVERNMENT	
International	• Encourage developments of STP technologies and technology transfer
National	• Removal of any subsidies for fossil-fuel generated electricity • Prioritise STP technologies for bilateral co-operation • Establishment of suitable industry structure, pricing mechanisms, contractual structure and performance specifications • Granting of all the necessary permits • Other normal IPP activities e g. counter guarantees • Development of a programme for pilot installations and commercialisation of STP technologies
Local	• Encouragement of renewable energies • Local planning issues
Rural electrification	• Development of a programme for pilot installations and commercialisation of STP technologies suitable for stand-alone operation • Development of suitable arrangements for attracting private investors to rural electrification projects
FINANCIAL PARTIES	•
GEF	• Grants to encourage pilot installations (both grid connected and stand-alone), based on the incremental cost of the STP development
Multilateral agencies	• [illegible]
Bilateral agencies	• Grants and soft loans during pilot and commercialisation phases
National and local governments	• Grants, loans and equity during pilot and commercialisation phases
Financial Institution (e g IREDA)	• Commercialisation of STP technologies
Equipment suppliers	• Invest equity in IPP development
Banks	• Loans
UTILITIES	• Power Purchase Agreements • [illegible]
DEVELOPERS	• [illegible] • Equity for STP plant (probably in conjunction with a conventional fossil-fuel plant)
OTHER	•
Turnkey contractors	• Construction activities. May also hold equity in the project company
Research institutes	• Development of STP technologies • Monitoring performance

INTERNATIONAL WORKSHOP ON SOLAR THERMODYNAMIC ELECTRICITY GENERATION, New Delhi, 1st March 1997

All the goals of this workshop were realised The following is a summary of these goals and some of the key findings of the workshop.

- Presented the preliminary findings of the ODA project
- Created awareness of the STP technology options and their current state of development amongst the audience of representatives from financial institutions, private financiers, development agencies, developers and Indian national and state government.
- Stimulated a lively debate between the participants and encouraged networking.
- The following comments were made by various departments of the Indian Government:

MNES
- An STP R&D programme is planned for India, including a feasibility study for a central receiver plant
- The Rajasthan solar zone has been set up with the goal of realising 1GW of installed solar by 2010
- MNES can see advantages to starting on smaller pilot projects (kW rather than MW)

IREDA
- IREDA have not financed any STP projects and currently have no formal STP loan structure in place
- IREDA are currently seeking to set up a STP technology development fund

- Identification of the barriers to STP development, and in particular the financial barriers

  - Lack of funding for small projects within India
  - The current prices of STP are uncertain to say the least, and estimates vary. There is no real "market" price, as there is currently no market. Projections of future prices are even more uncertain.
  - Perception (amongst traditional power developers) that the technology is too risky to consider

  Institutional barriers
  - Financially insecure utilities in India with no credit rating, and hence uncertainty surrounding any Power Purchase Agreements (PPA)
  - Political barriers

- Development of a strategy to overcome these barriers

  - The on-going Mathania project is designed to help overcome some of the uncertainty surrounding these technologies
  - There was a call for loans, support for feasibility and pilot projects from private developers

RECOMMENDATIONS

The environmental analysis in Section 2.8 has indicated that there is real potential for incorporating STP technologies into the refurbishment of old, inefficient coal-fired power stations in India. This type of project would have great environmental benefits, both due to the upgrading of the coal boiler, and due to the displacement of coal by the solar field.

What is required at this stage is a pre-feasibility study to assess the technical options available and to try to identify suitable power plants. This study would have to take into account the following:

- An installation of this kind is currently planned in Spain;
- KfW have had some talks with NTPC in India on this subject;
- The existing nature and timing of the maintenance / refurbishment programme for cola-fired power stations in India.

The results of the economic analysis in Section 2.4 indicate that parabolic dish technologies would be cost-effective compared to grid-extension in certain rural situations. Further research work is required to define the optimum configuration of plant (in terms of back-up energy sources and possibly storage options)

There is a running theme throughout several of the sections that highlights the need for quality projects, not purely in terms of hardware, but in terms of establishing the training and maintenance programme that will ensure the long term viability of the plant. This is particularly important in developing country projects, where some specialist component and skills will be imported and therefore will not automatically be available in-country. There is a need for a clear definition as to exactly what quality criteria are important, and what minimum standards need to be met.

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Annex 6. Review of recently published STP market predictions and support strategies
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Glossary

Banking power	The ability to export electricity to the grid from a site and import this electricity back onto the same site when required.
BOOT	Build, Own, Operate, Transfer
Captive power	On-site generation e.g. a diesel generator
DFID	UK Department for International Development (formally know as ODA)
DFR	Detailed Feasibility Report
DISS	Direct Inject Solar Steam
DPR	Detailed Project Report
GOI	Central government of India
GOR	State Government of Rajasthan
ICB	International Competitive Bidding
ICICI	Industrial Credit and Investment Corporation of India Ltd
IPP	Independent Power Project
IREDA	Indian Renewable Energy Development Agency Ltd (GOI Enterprise)
ISCCS	Integrated Solar / Combined Cycle System
JV	Joint Venture
KfW	Kreditanstalt fur Wiederaufbau (German Development Agency)
Load Factor	The net electrical output over a specified period divided by the maximum possible output during that period operating at design capacity. A solar-only plant is limited to lower load factors of around 25% by definition due to the periodic availability of solar radiation. Sometimes referred to as the capacity factor
MNES	Ministry of Non-Conventional Energy Sources (GOI Ministry)
NTPC	National Thermal Power Corporation (part of GOI)
CDA	UK Overseas Development Administration (recently changed name to DFID)
O&M	Operations and Maintenance
PACER	Programme for Acceleration of Commercial Energy Research
PPA	Power Purchase Agreement
REC	Rural Energy Corporation (GOI)
REDA	Rajasthan Energy Development Agency (part of GOR)
SEB	State Electricity Board (part of state governments)
SEGS	Solar Electric Generating System (normally refers to trough systems of the design installed in California)
Solar Irradiance	Power density of radiation incident on a surface. Irradiance is normally expressed in watts per square metre (W/m2)
Solar Irradiation	the incident solar energy per unit area of a surface, found by integration of irradiance over a specified time interval, often an hour or a day. Irradiation can be expressed in MJ/m2 of kWh/m2
STP	Solar Thermal Power
T&D	Transmission and Distribution (of electricity)
TDICI	Technology Development and Information Corporation India (part of ICICI)
TERI	Tata Energy Research Institute
PPA	Power Purchase Agreement
Wheeling power	The ability to export electricity to the grid from a site and import this electricity back onto a different site when required.

Conversion factors used

1 UK£ = 55 Rp.   1US$ = 35Rp.
1 crore = 10 million Rp.   1 lakh = 100,000Rp.   100 Paise = 1Rp.

1. Solar Thermal Power Background

1.1 Status of Solar Thermal Power (STP) Technology

Several technologies have been developed for generating electricity from solar thermal power The five most important variants are as follows:

1. Parabolic trough
2. Central receiver
3. Parabolic dish
4. Solar chimney
5. Solar Pond

A brief description of these technologies is included in Annex 1 There follows a summary of the most relevant activities and state-of-the-art for each of these variants.

1.1.1 Parabolic Trough

These technologies are the most technically developed and are the only ones which have been incorporated into commercial scale projects (in California in the 1980's). Current research activities focus on reducing operation and maintenance costs, and on generating steam directly in the absorber tubes

STP projects are eligible to apply for funds from the Global Environment Facility (GEF). It is understood that 3 STP projects will be supported under GEF in the near future, with approximately $50 million per project. It is likely that all of these will be parabolic trough projects.

Table 1: Current Status of Parabolic Trough Projects

Project Name	Country of development	Rated Solar Power (MWe)	Technology	Current Status
STEM / ARDISS / DISS	Spain	R&D	Development of Direct Solar Steam (DISS) technology. Refining methods to cut down heat flux gradients and secondary concentrators. A test centre at Almeria is planned.	New DISS proposal with the EC
Mathania, Rajasthan	India	35	Open to ICB, but probably parabolic trough [this project is described in full detail later]	Bidding papers compiled, some political delays
Theseus	Crete, Greece	50	SEGS system (as used in California) with oil back-up. 55% solar share planned.	Pre-feasibility work done. Proposal to DG XVII for funding for this demonstration project
	Mexico	31.2	Integrated Solar Combined Cycle System (ISCCS), 135-290 MWe total. Low solar share (around 10%).	Feasibility study completed. Applied to GEF. Some political delays.
Ouarzazate	Morocco	80	SEGS system with 51% solar contribution	Further studies underway to re-assess

1.1.2 *Central receiver*

Central receiver systems are undergoing continued development, most notably in the USA (Solar 2) and at Almeria in Spain Some commercial development are currently in the planning phase. A review of central receiver technologies is being carried out in India, funded by the Ministry for Non-Conventional Energy Sources.

Table 2: Current status of Central Receiver Projects

Project Name	Country of development	Rated Solar Power (MWe)	Technology	Current Status
Solar 2	USA	10 (R&D plant)	Central receiver using a mixture of sodium and potassium nitrate as heat transfer fluid. Includes salt storage tank.	Operational
Phoebus project	(Jordan)	30	Volumetric air receiver into Rankine cycle or ISCCS	Jordan project currently on hold. Imminent commercial product available
Solgas / Colon	Spain		ISCCS with solar share of about 7%	Proposal to DG XVII for funding this demonstration project

1.1.3 *Parabolic dish*

Systems are under development in Australia, Germany, Spain USA and Japan. Commercial products are due to enter the market place in the near future

Table 3: Current Status of Parabolic Dish Projects

Project Name	Country of development	Rated Solar Power (MWe)	Technology	Current Status
Tennant Creek	Australia	2 MWe	27 "Big Dishes" generating steam for a Rankine turbine	One Big Dish built and tested
	Germany & Spain	9 & 25 kWe	Stretched membrane dish with stirling engine	9 kWe prototypes tested, design studies completed for 25kWe version.
	UK/Armenia/Crete	1	Fixed bowl concentrator with tracking absorber / gas turbine.	Pilot system being constructed under a Joule research project

1.1.4 *Solar Chimney*

Limited research work has been carried out on solar chimneys, although a commercial installations is already planned for India.

Table 4: Current Status of Solar Chimney Projects

Country of development	Rated Solar Power (MWe)	Technology	Current Status
Sri Lanka			Pilot installation
Rajasthan, India	200	1 km high chimney to be built in 5 stages, with a pre-heating water reservoir of almost 100 million m^2.	The Letter of Intent signed in 1995 with the Government of Rajasthan required 35 MWe to be commissioned by 1997. There has been no development to date.

1.1.5 Solar Pond

The only recent solar pond development was a 6000 m^2 pond constructed in Gujarat, India in 1993. This is still operational and supplies process heat for a dairy.

1.1.6 Other general activities

The following is a summary of other recent developments and activities in the solar thermal power field which are either non-technology specific or non-project based research work.

Table 5: Current Status of Other STP Activities

Name	Description
Egypt	Presentations to NREA by the IEA SolarPACES START team. NREA planning a feasibility study
South Africa	Northern Cape Solar Thermal Steering Committee set up. Membership includes ESKOM, who are currently undertaking a pre-feasibility study into a solar thermal plant for the Northern Cape
Namibian	Solar thermal pre-feasibility study underway, with assistance from GTZ.
Mediterranean	Market study completed in 1992
Nevada, USA	Solar Development Zone set up by the Corporation for Solar Technology and Renewable Resources. Grant from the US DOE includes STP projects.
ESTIA	The European Solar Thermal Power Generation Industry Association was set up in April 19997
SolarPACES	This IEA Task continues to be active in the collaboration of STP research and project development. The UK have recently joined this Task.
Almeria, Spain	Ongoing research on central receivers, troughs and dishes
National Solar Thermal Test Facility, Albuquerque, USA	Ongoing research work on central receivers, dish systems and troughs
Israel	A new type of receiver is under development called the "Porcupine." It is designed for high temperature, high pressure operation with gas turbines.
Germany	On-going project led by Pilkington Solar on the integration of solar thermal power plants into regional electricity supply structures. Funded by DG XII and due for completion January 1998.
Germany	On-going research and testing of advanced absorbers for dish systems using heat pipes. Lead by DLR, funded by DGXII and due for completion in January 1999.

1.1.7 Status of STP technologies in developing countries

It is useful to categorise the current state of development of each technology (Table 6). This categorisation has been compiled in the context of specific experience in developing countries, and does not represent the current world-wide state of the art. This Table illustrates the fact that there are currently no STP technologies which have been demonstrated at a commercial scale in developing countries.

Table 6: Development status of STP Technologies in Developing Countries

TECHNOLOGY	Research	Development	Demonstration
Parabolic trough	Pittie Renewable Energy Systems (Fresnel lens)	Brown Boveri was developing a system in Hindustan, but stopped development some years ago Test system imported from Germany and installed at the Tata Institute in Bangalore	Small (50kW) MAN system demonstrated at Gual Pahari near Delhi 35MW system planned at Mathania
Central receiver	Feasibility study planned in India		
Parabolic dish	Solar Power Corporation Power (Energy Consultants)	Some small pilot systems installed in India (e.g. Salojipally village), but not a great success	
Solar chimney	IIT, Delhi	Small pilot installation in Sri Lanka	200MW planned in Rajasthan
Solar ponds		Bhuj solar pond in Gujarat	

1.2 Case Study Installations and projects

1.2.1 MW$_e$ Solar Thermal Power Plant, Mathania, Rajasthan

1.2.1.1 Background

In 1986, M/s Ballarpur Industries Ltd (BILT), a Thapar group flagship proposed to install the 30 MW STP in Punjab as Independent Power Producer (IPP) and sell the power to the Punjab State Electricity Board (PSEB) As the estimated cost of power from STP was Rs 1.68/kWh against the prevailing rates of Rs 1.16/kWh at that time, PSEB did not approve the proposal. Thereafter BILT approached Government of India for subsidizing the project, to the extent that their power cost equals that of PSEB

However around that time, Punjab was declared as disturbed area on account of militant activities and as such it was not thought of prudent to make any major investment there. Rajasthan was then suggested as an alternative. Accordingly, site surveys were conducted in Rajasthan. Jodhpur and areas around it were found to be most suitable. Cost of the project at that time, in 1988, was estimated to be around Rs 100 crore (at $ 1 = Rs 12.50).

While these things were going on, BILT lost interest and slowly faded out of the picture. LUZ also went bankrupt. In the meantime, other states like Gujarat, Uttar Pradesh, Andhra Pradesh and Bihar had also shown their interest in similar kind of projects. Consequently, in 1990, Secretary, MNES (then department) formed a working group for preparation of a comprehensive proposal for setting up 30 MW Solar Thermal Power plant in the country. The working group comprised nominees from:

- Department of Power (DoP), Government of India
- Central Electricity Authority (CEA)
- Rural Energy Division, Planning Commission
- Project Appraisal Division, Planning Commission
- Bharat Heavy Electricals Ltd. (BHEL)
- Rajasthan State Electricity Board (RSEB)
- Rajasthan Energy Development Agency (REDA) and
- Department of Non-conventional Energy Sources (DNES)

It was decided that the first MW size solar thermal power plant should be taken up as R&D - cum - demonstration project, with an objective of replication of such plants in future. The emphasis was on optimum utilization of indigenous know-how and transfer of technology. In the interim period, DNES and KfW (an international funding agency of the West German Government) commissioned Fichtner (Germany) and Fichtner (India) to prepare a feasibility report for the sites of Jodhpur in Rajasthan and Bhuj in Gujarat. This was a sequel to initiation of exploratory discussions by Government of India with the Government of West Germany for possibility of their extending aid/soft loan for such a project.

The working group concluded that parabolic trough type collectors were more promising compared to the central receiver type, mainly because 6 units of 30 MW installed in California were of this type. Out of two alternative plant sizes of 10 MW and 30 MW, considering the objective of ultimately commercializing the technology and taking into account the provenness of 30 MW unit size, it was decided to go in for plant of this size only. The group also examined the available data for different proposed sites and came to the conclusion that Jodhpur was most appropriate site for such a venture. The total project cost for 30 MW (Solar alone configuration) STP was estimated at approximately Rs 160 crore which included costs of grid inter connection and other auxiliary systems. Thus, taking an internal rate of return of 12%, the long range marginal cost of generation works out to be Rs 5.64/kWh. The group concluded that if financial package, comprising grants-in-aid and soft loans were also considered, the cost of generation would be approximately Rs 2.61/kWh for solar alone configuration [1].

1.2.1.2 Technical details

The project is to be the subject of International Competitive Bidding, so the technology itself has not been specified. Current thinking is that it is likely to be a 135-140 MW combined cycle hybrid plant with 100 MW of naptha-fired combined cycle and 35MW of parabolic trough plat feeding into the bottoming cycle.

1.2.1.3 Present Status

Presently, land had been acquired by the Rajasthan government at Mathania. A weather station too had been set up there. This will be monitored by the Central Arid Zone Research Institute (CAZRI), a central government institution. REDA has commissioned the National Environmental Engineering Research Institute to prepare the Environmental Impact Assessment.

A separate project company, named Rajasthan Power Corporation Ltd., has been incorporated, which most probably would carry out the actual work. Some of the guideline policies are still being formulated, both at MNES as well as at Rajasthan Government level. Once the policies are in place, global competitive bidding for the project execution would be done. The tender documents for the bidding are under preparation. Obviously, it will take quite some time before the actual work starts on the project.

Further details on the financial structure of the project are included in Section 3.

1.2.2 kW Solar Thermal Power Plant, Gual Pahari

This solar thermal power plant (STP) was put up as a demonstration system, at the Solar Energy Centre (SEC) of the Ministry of Non-conventional Energy Sources (MNES). When the work was initiated, the site was in complete wilderness and as such a lot of money was spent on site-development alone. The plant, based on Luz technology, incorporating parabolic trough collectors, was fully imported at a cost of about Rs 4.0 crore (about £730,000). The technical specifications are given in Table 7.

Table 7: 50 kW STP, Gual Pahari - Technical Specifications

Capacity	50 kW
Collectors	Parabolic trough
Total collector area	1280 m^2
Collector aperture	2.2 m
Collector's orientation	North - South
Collector loops	4 nos.
Heat transfer fluid (HTF)	Hytherm - 500
Field output temperature	290 C
Field input temperature	229 C
Normal HTF flow rate	3.8 kg/sec
Minimum HTF flow rate	1.7 kg/sec
Maximum HTF system pressure	10 bar
Cutoff insolation	200 W/m^2
System flow rate at desired output	940 kg/hr
Inlet temperature of steam	238 C
Inlet pressure of steam	31 kg/cm^2
Turbine rating	60 kW
Turbine speed	6650 RPM
Maximum turbine speed	6900 RPM
Hot HTF storage capacity	4 m^3
Thermodynamic cycle	Rankine cycle

The system was commissioned in April, 1989. It remained in operation till October 1990, but except at the time of commissioning, when about 56 kW of electricity was produced, Gual Pahari STP never attained its full design capacity. The STP always lacked trained manpower which resulted in its poor maintenance and ultimately to its closure. Apparently no technical or techno-economical evaluation has ever made If such kind of study has been undertaken anytime in the past, it was not made public and hence it is difficult to say as to how did the system perform when it was operational.

After a lapse of almost 5 years, the revival work on Gual Pahari STP was initiated in September, 1995 A new technical team was assigned this task. While two loops of the collectors arrays were made operational in November, 1995, the third one was commissioned in January, 1996. The STP is stated to be capable of generating 20 kW of power now. Table 8 shows the milestones of this STP development.

Table 8: 50 kW Solar Thermal Power Plant, Gual Pahari - Milestones

Commissioning	April, 1989
Operational up to	October, 1990
Revival work taken up	September, 1995
Repair and testing of boiler	October, 1995
Two solar loop (50%) made operational	November, 1995
Demo steam generation and turbine operation	November, 1995
Revival of 3rd solar loop taken up	November, 1995
Revival of 3rd solar loop (75%) completed	January 19, 1995
Demonstration power generation	February 3, 1996

1.2.2.1 Operational experiences of Gual Pahari STP

The two major problems faced in operating the Gual Pahari STP, are as follows.

(a) **Non-availability of spares.** A number of reflectors (mirrors) had got broken but the same can not be replaced as the original manufacturers (M/s Man of Germany) are no more producing these mirrors and mirrors of same quality and contour are not available indigenously. As a result, some collectors are rendered non-operational.

Similarly, glass casings of evacuated tube absorbers have broken. First of all it is difficult to procure same type of glass tubes and even if those are procured, it is simply not possible to seal and evacuate the tubes at the site. One fall out of this is the exposure of the metallic absorber tubes to the atmosphere. This exposure then leads to the oxidization of the metal and ultimately to, deterioration of selective coating.

(B) **Manpower.** Since the inception of the project, there had been problems of having manpower of sufficient technical knowledge, training and experience. The problems is more acute at field level. In addition, the manpower appeared to have been allocated in a sort of stop-gap arrangement rather than with a long term perspective. This has resulted in a poorly maintained and operated STP.

Apart from the above mentioned problems, some technical problems too have been faced. For example, it is reported that the.metallic holding device, which holds the mirror, gives way under thermal expansion and contraction. The mirror then gets broken.

1.2.3 Hindustan Brown Boveri, Baroda Solar Project

1.2.3.1 Scope and objectives

The aim of the project was to develop a high efficiency solar concentrator to deliver thermal energy in the temperature range of 250-300°C.

The objectives were as follows:

1. To review different types of concentrators and select the most suitable type.
2. To develop a methodology for optical design of this solar concentrator.
3. To establish manufacturing technology for the above.
4. To develop the prototype and evaluate its optical and thermal performance.

1.2.3.2 Selection of concentrator type

The selection criteria included points like (I) operating temperature, (ii) annual performance, and (iii) cost per m^2.

The concentrating collectors, capable of delivering heat at 300°C were:

* evacuated CPCs
* Fresnel lenses
* Fresnel mirrors
* fixed mirror, moving receiver
* parabolic troughs

Yearly performance of non-evacuated and evacuated parabolic troughs was compared with that of other collectors considered. The comparisons concluded that a parabolic trough excels all the other types, in all the climatic conditions, for the temperature requirements of 250-350°C

1.2.3 3 Design of parabolic trough concentration and its manufacturing

Considering on various aspects, including allowances for allowable errors, it was decided to go in for selective coated, non-evacuated absorber. The requirement of optimal concentration ratio was in the range of 22-26. The aperture width was fixed at about 2.1 m, whereas a silvered acrylic mirror was chosen as reflector. The length of the module was 6 m. 'Servotherm-special' oil was selected to be used as heat transfer fluid. 'Servotherm' was marketed by Indian Oil Corporation Ltd.

The structure of parabolic trough consisted of a longitudinal torque tube with parabolic ribs fixed on it, at specified intervals. The heat receiver assembly was of concentric metal-glass tubular design with a selective coating. The glass envelope was a borosilicate glass tube, supported over the absorber tube by polymer spacer rings. The whole parabolic trough was supported at the ends by means of drive shaft and suspension plate arrangement. The automatic sun tracking was incorporated by means of a shadow band sensor.

The rib of the parabolic trough was manufactured on CNC nibbling machine. The profile was cut on the steel sheet as per the computer programme. The rib was in two identical halves, each half being a semi-parabola. To achieve alignment of the ribs, holes in the fixing plates were drilled using a drill jig and the welding of these plates to the torque tube was done, using especially designed fixture.

Since the intercept factor, slope error, geometric concentration ratio and specularity of the mirror play a vital role in determining the optical quality, and hence the efficiency, of the concentrator, these were measured using laser technique.

The manufacturing accuracy of the backup structure was found to be adequate, except for a sag over a small portion of the mirror between the ribs

1 2.3.4 Operational experience

The thermal performance of the concentrator was much lower than the theoretical value. On account of sagging of the reflector between the ribs, there was a reduction of overall intercept factor, to the tune of 25%. Problems were also encountered in the operation of the fluid loop and in the reflector material. The *3M* film was found to degrade rapidly on site, within a week.

It was concluded that the design performance could be attained with the manufacturing techniques adopted in the project and but by improving the deficiencies. It was also found that the laser technique used could effectively characterize the optical properties.

1.2.4 Solar thermal process heat plant, developed by Indian Institute of Science (formerly Tata Institute), *Bangalore* [ii]

Under the Indo-US Collaborative programme the Indian Institute of Science (I.I.Sc) and the University of Houston installed a large medium temperature solar-Industrial process heat (SIPH) system using Parabolic Trough Concentrators (PTC) at the Government Silk Weaving factory at Mysore.

The project was divided into two phases: Development of high efficiency PTC; and the design and setting up of a system for an agro-based industry.

Three PTC designs having semi-monocoque, sandwich and stiffened rib structures were identified to study their structural designs. Wind load studies were conducted on the PTC with semi-monocoque structure but due to its heavy weight was found to be unsuitable for large systems. The PTC with stiffened-rib using laminated mirrors of M/s. Glaverbel, Belgium was finally selected.

Solar Steam Generating System

The objective of the project is to demonstrate the technical and economic feasibility of generating low pressure process steam with solar energy. The system consists of proven conventional, industrial steam generating equipment.

Collector Development

The PTC's reflecting surface is mounted on a stiffened parabolic shape structure. The receiver, a circular tube with a selective coating is enclosed in a concentric glazed glass envelope and located centrally along the reflector focal line. The glazing protects the coating from environmental degradation and reduces convection and radiation heat losses. The receiver's optical and thermal efficiencies are 72% and 60% (at 200°C) respectively. The driving system tracks the sun while in operation and the solar radiation is focused on the receiver assembly. This energy is absorbed by the working fluid circulating through the absorber tube.

Reflector and its support Structure

The highly reflective, chemically tempered laminated back silvered glass mirror of M/s. Glaverbel, Belgium 0 8mm thick is backed by 0.8 mm thick steel sheet. The nine ribbed parabolic shape structure which is accurately aligned to the torque tube which rotates in the bearings mounted on two pylons. One of the shafts at one end of the PTC module is connected to a driving unit for tracking. The detailed specifications are given in Table 9.

Solar Steam Generating Plant

The steam generation system installed at Government Silk Factory, Mysore in Karanata includes 192M^2 of PTCs, a flash boiler and circulating pump. Each of the five rows of collectors consisting of six modules is supported by eight pylons The six modules of PTCs are connected to a common drive and a tracking unit. The pump circulates water at 3137kg/hr through solar concentrators where it is heated to 179°C under peak insolation.

The hot pressurised water enters the flash boiler where it is converted into steam at 4.56bar and 150°C and flows into the plant steam main Make up water from a water treatment plant is pumped into the deaerator, located on the top of the flash boiler drum.

Collector Field Controls

The control systems for the PTC position the collector during the day with respect to the sun and defocus the mirrors in emergencies.

Controls for Boiler System

Simple, on-off controls have been provided for safe and effective operation of the steam generation.

Performance of KSIC System

The performance data has been recorded for the last two years. Some typical data collected in January 1990 on various dates is given in Annex 2.

On 20th January, 1990 the data indicates that the collector field efficiency varies from 30% to 60% depending on the time of sunshine The peak efficiency achieved is 60%. After 5 hours of operation, the steam pressure reached 4.7kg/cm^2 at 156°C. On the subsequent day the solar insolation was high and the steam temperature reached 149°C within 4 1/2 hrs of operation. The graphs illustrate direct normal bean radiation, incident beam radiation and collected energy. The data given in the Tables shows the consistency of the results and high efficiency of the system at Mysore Silk Factory, Mysore.

Problems encountered at KSIC, Mysore Plant

During the last three years, a number of teething troubles were experienced. Some are due to poor maintenance and some are due to design failures Major faults are listed below:

1. Driving Mechanism: The motor is always coupled to the gear box. It is not possible to disengage the gear box from the collector shaft (Torque tube). During a power failure period, the solar energy will be concentrated on the receiver tube which most of the times, breaks glass envelope due to excessive heat generation.

2. Thermal expansion of the receiver tube during the fluid flow is not taken care in designing the receiver tube connections This resulted in malfunction of the subsystem.

3 In Honeywell tracking mechanism, there is no provision for limit control. Automatic Control mechanism is also failing very often

4 The present water circulation pump is producing a lot of noise when the temperature of the water in the line exceeds 125°C

5. Cracks were developed on most of the reflecting mirrors within 4 years. But there was no change in reflectivity of the mirrors.

6. Flexible hose connection is to be redesigned.

The overall performance of the plant could be improved by studying the analysing the failure rate, component defects, efficiency of the system and down time. The necessary modifications in the design, component and material selection, subsystem engineering are to be carried out

Lessons Drawn and Benefits Accrued

- Sufficient experience was gained in the design, construction, erection and commissioning of a PTC system suitable for SIPH.
- The plant has been working successfully and producing steam 100 kg/hr at 4 kg/cm^2 pressure.
- The collector field efficiency is 60% at 180°C
- Maintenance and operation problems are identified for continuous operation of the plant.
- The sun shine hours at Mysore are less than expected and the plant could not be operated more than 200 days in a year.
- Even at this level of operation, coal saving is appreciable.
- From manual mode, the plant should switch over to automatic operation mode
- It established the technical feasibility and competence of Indian scientists to build such plants in India
- Since the supplier of reflecting glass mirror went out of business and there are no other suppliers to supply a similar mirrors, the entire designs of collector and associated structures are obsolete and not directly viable However the project gave the scientists, engineers concerned good experience and confidence to tackle similar equipment and system design.

Table 9: System Specifications

Parabolic Trough Concentrators	
Aperture length	3050 mm
Aperture width	2100 mm
Rim Angle	92°
Focal length	505 mm
Reflectivity of the mirror	0.92
Absorber material	Carbon Steel
Outside diameter	33 mm
Inside diameter	28 mm
Solar selective coating	Black Chrome
Glass Envelope	Pyrex
Outside diameter	60 mm
Inside diameter	55 mm
Solar Collector Field	
Area of the collector field	192m^2
Arrangement of the collector field	30 modules arranged in six rows, each row containing six modules in series
Orientation	North-South horizontal
Tracking	Single Axis East-West
Control System	One field controller five local controllers
Heat transfer fluid	Pressurised water
Flow rate	3000 kg/hr.
Inlet/outlet temperatures (collector)	150°C / 179°Cfield
Inlet/outlet pressure	8 / 12 kg/cm^2
Specifications of the Boiler/Flash Tank	
Drum operating pressure	4.85kg/cm^2
Drum design pressure	7.50kg/cm^2
Design temperature	180°C
Max. evaporation capacity of boiler	250kg/hr

Saturated Steam temperature	150°C
Steam flow rate	100kg/hr
Flash boiler inlet line design pressure	$15kg/cm^2$
Flash boiler inlet line operating pressure	$12.0kg/cm^2$
Flash boiler inlet line operating temperature	175°C
Approximate dimension of boiler drum	Dia 800mm, length 2500mm
Feed Pump	
Normal output	300 litres/hr
Discharge Pressure	$7kg/cm^2$
Reciprocating Pump	
Normal output	7100 litre/hr
Suction Pressure	5 kg/cm^2(abs)
Discharge Pressure at normal output	$13kg/cm^2$(abs)

1.2.5 Solar Power Corporation

In 1993, Solar Power Corporation (SPC) submitted a proposal, titled '*Development of Technology for Generation of Low Pressure Steam' using Solar Thermal Energy and Demonstrating It on a Commercial Scale'*, to Industrial Credit & Investment Corporation of India (ICICI) under the Programme for Acceleration of Commercial Energy Research (PACER), a programme funded by US Agency for International Development (USAID). The proposal had three collaborators, namely. SPC as the manufacturers, Central Salt & Marine Chemicals Research Institute (CSMCRI), Bhavnagar as the research institution and Excel Industries Ltd., Bhavnagar as the end users. The main objectives were:

1 Development of a technology for generating low pressure steam using solar thermal energy
2 Demonstrating the technology on a commercial scale

The idea was to use the technology afterwards for various applications like desalination, refrigeration, drying and electricity generation.

The proposed solar thermal plant comprised an array of four, square dish concentrators (SDC) of 300 m^2 nominal area each; a receiver at the focal point of the dish, piping etc. for transferring heat transfer media, such as pressurized water on thermic fluid, to the required application. The square dish has reflecting surface, made up of number of curved mirrors, aligned to focus sun rays to the focal point. The dish has two-directional tracking. The dish is designed and produced by Power Kinetic Inc. USA

The total project outlay for 3 year duration was Rs 7.87 crore. While SPC were ready to put some amount of funds, they were not in a position to share the project cost to the extent of 25% as insisted upon by ICIC. Thus, due to lack of funding, the whole project remained unrealized.

1.2.6 Luz, Punjab

Another unrealised project in India (Punjab) was for a 30MW parabolic trough system, proposed by Luz in 1987. Further details of this proposed project are included in Section 3.4.2.1 The reasons for the failure of this proposal are not known.

2. Technological Assessment

2.1 Electricity supply and demand factors

2.1.1 Electricity demand pattern in India

2.1.1.1 Installed capacity and generation

During the five decades of post-independence period, India has made note-worthy progress in the field of power generation. The power generating capacity, owned and operated by utilities has grown at a compound rate of over 10% per year since 1950. The total installed capacity till March, 1995 is 81,164 MW, of which more than 60% had been added since 1980 (Figure 1).

In addition to installed capacity, gross utility generation also increased rapidly, from 5.1 TWh in 1950 to 351 TWh in 1994-95, registering a compound growth rate of 9.7% a year. The average plant load factor of coal-based thermal power plants has remained below 57%. Most of the power generating capacity is under government control. Only about 4.4% of the total power generating capacity is in private sector.

Currently, the central government owns 31% of the power generating capacity in the country. It is reported that in next five years period (Ninth Five Year plan), starting 1997, a capacity of 57,000 MW would be set up [iii].

An assessment of electricity demand in the year 2020 places electricity requirement at 1300 billions kWh as compared to the actual consumption of about 365 billions kWh in 1993-94. At the present rate of capacity utilisation, the requirement of generation is worked out to be 378,00 MW, about four times the present installed generating capacity in the utilities [iv]. The relevant data are summarised in Tables 10 and 11 and Figure 1.

2.1.1.2 Electricity consumption

In spite of this all round progress, the per capita consumption of electrical energy is low at 283 kWh (in 1992-93) as compared to over 15000 kWh in Northern America and between 5-10000 kWh in most of the European countries. Still, the demand for electricity has been increasing at faster rate compared to the rate it is being made available. Electricity consumption grew at an annual compound rate of 10% during the period 1950 - 1993/94.

The pattern of consumption has changed very much during the past decades. The rural electrification programme along with highly subsidised electricity, has led to a rapid increase in electricity consumption in the agricultural sector has increased at the faster rate of 15.3% per annum during the period 1950/51 to 1993/94.

In the domestic sector, electricity consumption increased at a compound growth rate of about 10% a year during the last four years, thereby nearly doubling its share in total consumption.

The industrial sector, though still accounting for the highest share in total electricity consumption, registered a decline in its share in total consumption, from 70.6% in 1965/66 to 40% in 1993/94. One of the reasons could be that a large number of industries are increasingly relying on captive power because of erratic and poor quality grid supply. As on March 31, 1992, the total captive installed capacity was 10000 MW.

global warming. The exhaust emissions are particularly harmful to the flora and fauna of the islands.

These are the types of issues which start to make STP plant a more appropriate generating technology for these remote areas. Parabolic dish systems are particularly appropriate for these applications. In order to achieve an acceptable capacity factor, a hybrid system would be required, perhaps with a diesel generator back-up In this context, the STP plant would be saving diesel fuel costs, and not diesel capacity. However, in these remote areas, even modest savings in diesel fuel may justify the investment

Table 10: Generating capacity (in megawatts), electricity generation (in gigawatt hours), and per capita consumption (in kilowatt hours)

Region	Capacity (MW) *		Generation (GWh) *		Percapita consumption (kWh)**	
	1992/93	1993/94+	1992/93	1993/94	1992/93	1993/94+
Rajasthan	1733	1942	8592	8517	246	254
All India	72330	76750	301362	324163	283	299

* Utilities only
** Utilities and non-utilities
+ Provisional
Source. TEDDY 1996/97

Table 12: Power requirement, supply and deficit (1991/92 to 1994/95)

	All India peak power (MW)				Rajasthan peak power (MW)			
	Demand	Availability	Deficit	Deficit (%)	Demand	Availability	Deficit	Deficit (%)
1991/92	48,055	39,027	-9,028	-19	2,100	1,979	-121	-6
1992/93	52,805	41,984	-10,821	-21	2,300	2,228	-72	-3
1993/94	54,875	44,830	-10,045	-18	2,550	2,425	-125	-5
1994/95	57,530	48,066	-9,464	-17	2,660	2,412	-248	-9
	All India energy (million kWh)				Rajasthan energy (million kWh)			
1991/92	288,974	266,432	-22,542	-8	13,220	13,030	-190	-1
1992/93	305,266	279,824	-25,442	-8	14,317	14,081	-236	-2
1993/94	323,252	299,494	-23,758	-7	16 070	15,089	-981	-6
1995/96	352,260	327,281	-24,979	-7	17,000	16,080	-920	-5

Source: TEDDY 1996/97

Table 11: Installed capacities (in megawatts) of utilities (31st March, 1992 to 31st March, 1994)

	Hydro		Thermal		Diesel & Wind		Gas		Nuclear	
	All India	Rajasthan	All India	Rajasthan	All India	Rajasthan	All India	Rajasthan	All India	Rajasthan
1992	19,194	967	44,792	765	200	0	3,095	0	1,785	0
1993	19,575	968	46,597	765	225	0	3,928	0	2,005	0
1994	20,379	968	49,177	975	339	0	4,883	0	2,005	0
% increase	4	0	6	28	51	0	24	0	0	0

Source: TEDDY 1996/97

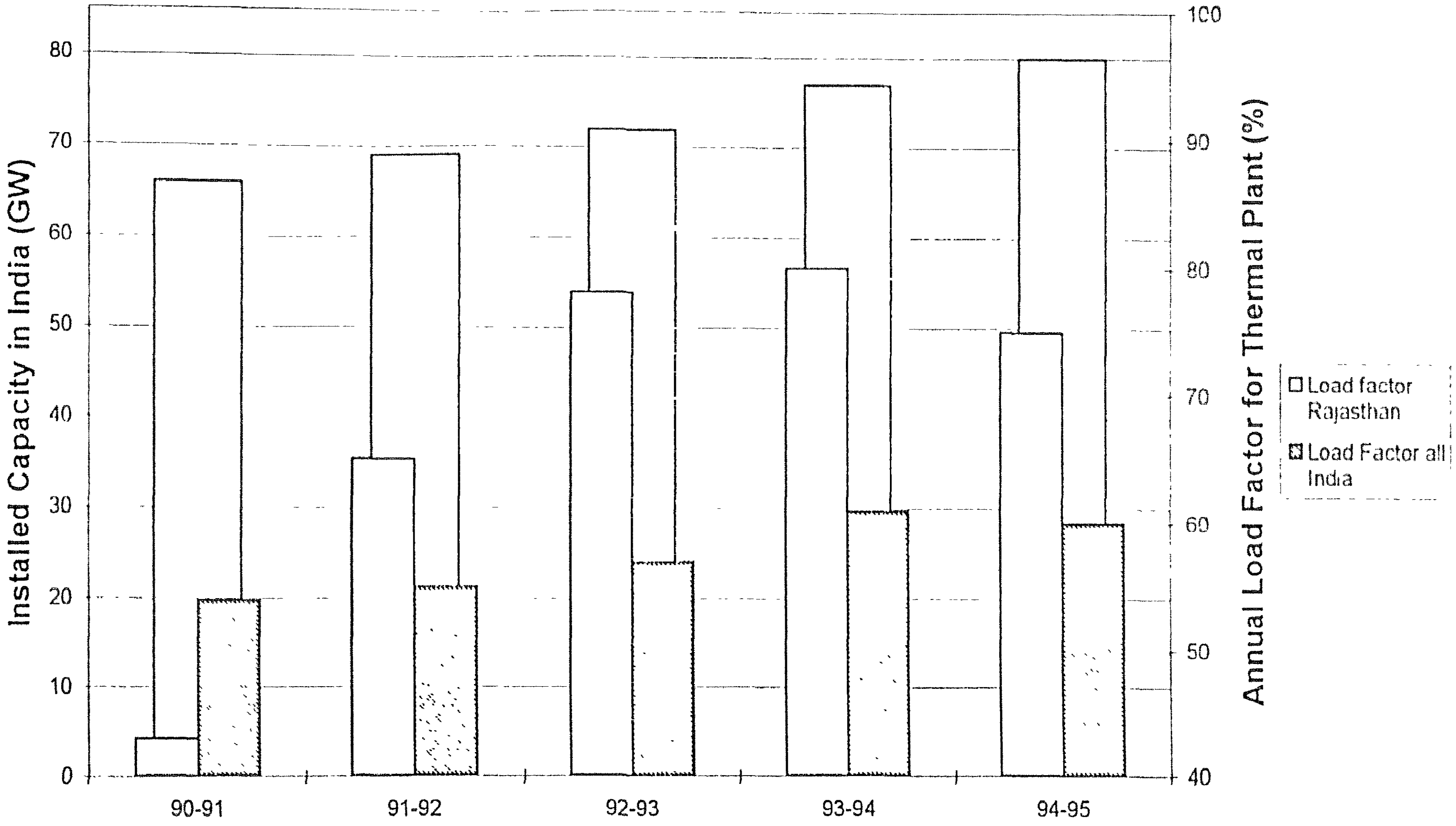

Figure 1: Installed Capacity in India and Load Factors

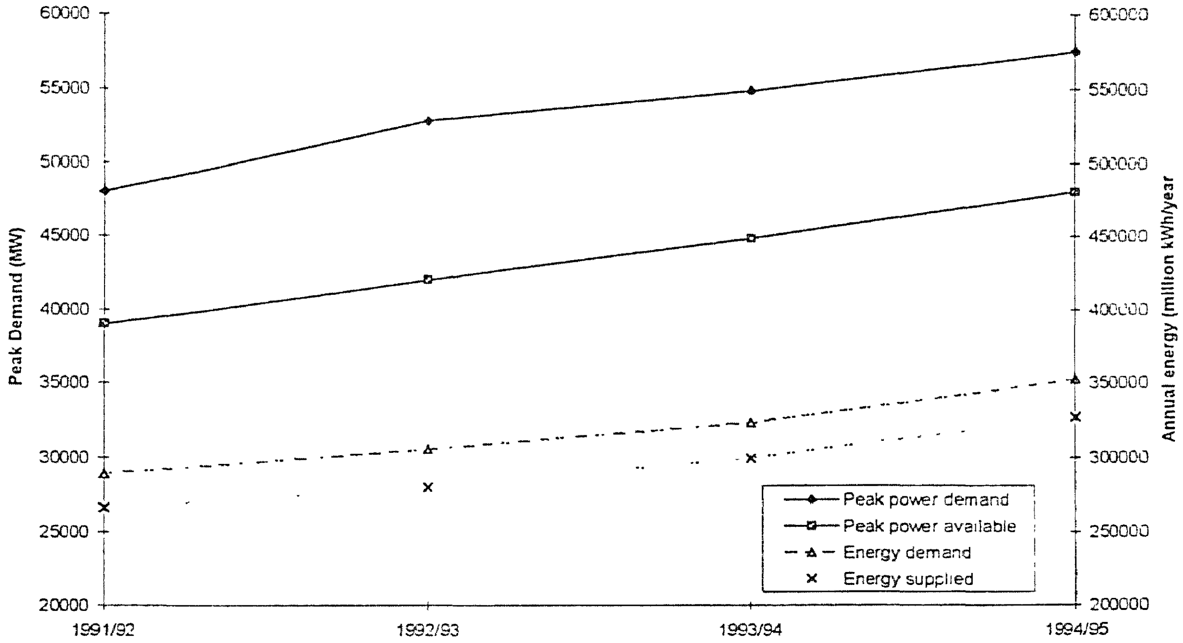

Figure 2: Electricity Demand and Supply Deficit in India

Table 13: Demand for power in 1996-97

Region	Energy requirement (million kWh)	Peak load (MW)
Northern	129,600	24,200
Western	121,200	19,600
Southern	103,100	18,200
Eastern	56,000	10,300
North-eastern	6,200	1,400
Andaman Island	140	40
Lakshadweep	20	4
All India	**416,300**	**73,700**

Source: 14th Electric Power Survey of India

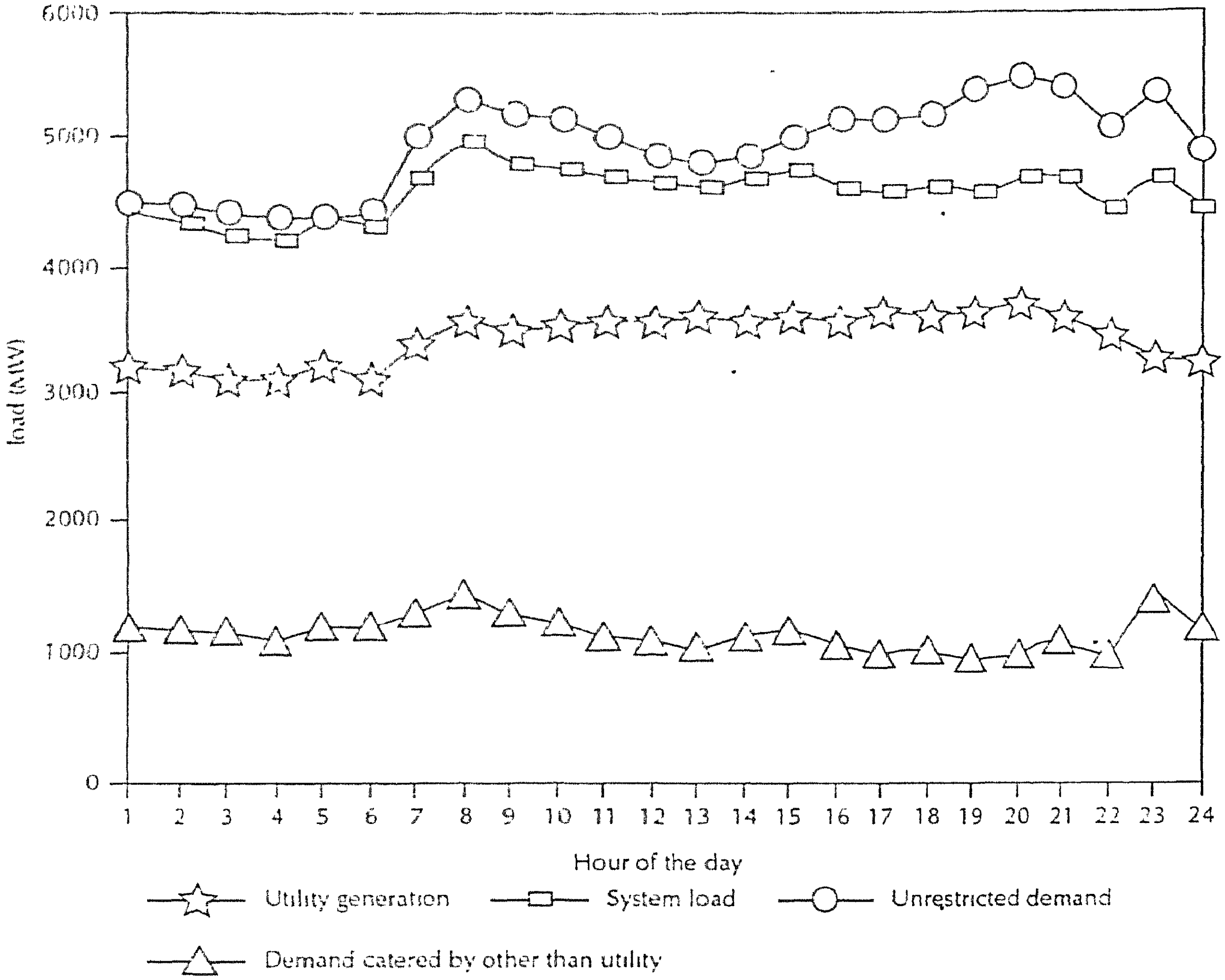

Figure 3: Daily Load Profile for Gujarat

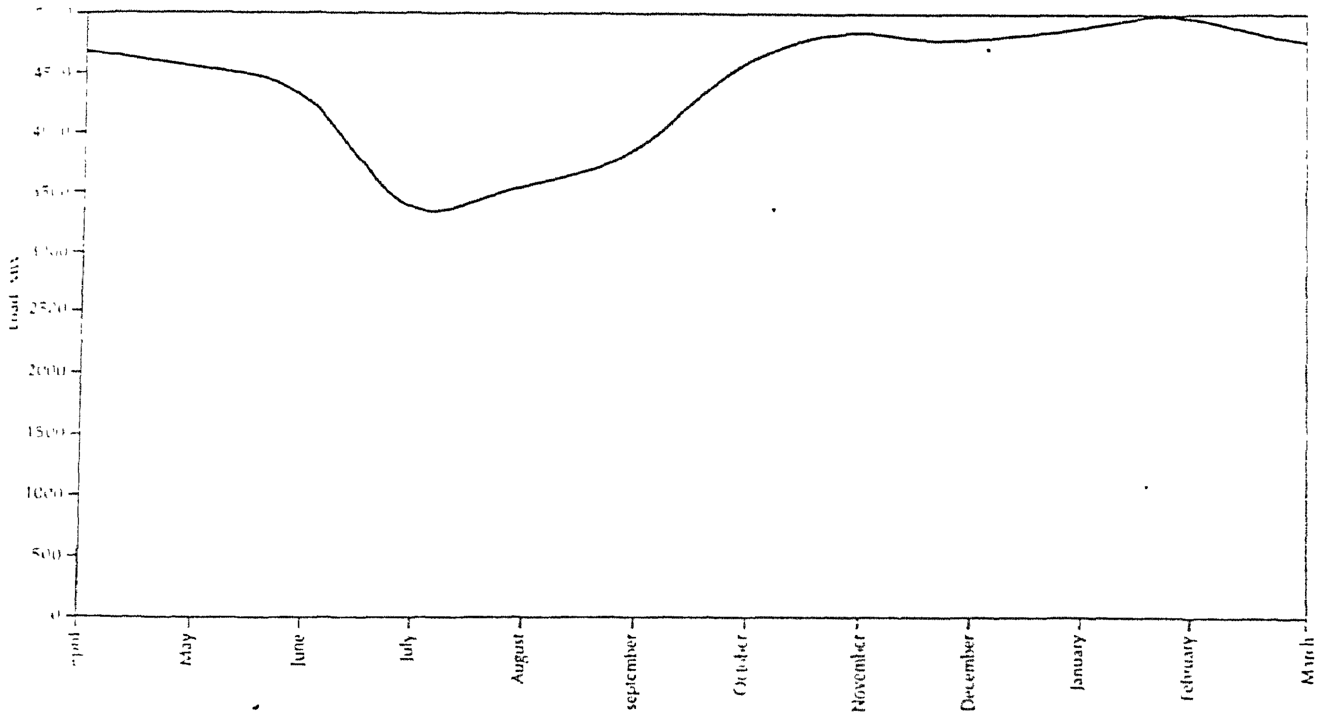

Figure 4: Monthly maximum system demand for Gujarat (1995 to 1996)

Table 14: Peak day load for Gujarat

Year	Average load (MW)	Maximum load (MW)	Load factor
1992 - 93	3658	4280	0.85
1993 - 94	4210	4580	0.92
1994 - 95	4582	4981	0.92

Table 15: Transmission and distribution losses (in percentage): 1980/81 to 1993/94

State	Transmission & distribution losses including unaccounted commercial losses					
	1980/81	1985/86	1990/91	1991/92	1992/93	1993/94
Rajasthan	26.6	26.2	25.8	23.1	22.7	24.9
All India	*	21.7	22.9	22.8	21.8	21.4

* Not available
Source: TEDDY 1996/97

Table 16: Unit cost & tariff (in paise/kWh) of electricity (1990/91 to 1995/96)

	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96*
Rajasthan						
Unit cost	114.59	113.31	130.60	149.40	169.00	188.90
Tariff	92.91	93.12	102 15	109.05	135.23	147.53
All India Average						
Unit cost	108.59	116.80	137.44	144.01	159.92	170.11
Tariff	81.80	89.06	105.27	117.97	132.88	140.72

* Annual Plan
Source: TEDDY 1996/97

Table 17: Consumer category wise average tariff (in paise/kWh): 1994/95

Utility	Domestic	Commercial	Agricultural	Industrial	Railways	Outside state	Overall average
Rajasthan	98.70	208.40	32.60	202.70	208.40	123.80	135.23
All India Average	92.80	203.39	21.82	211.58	248.55	109.53	132.88

Source: TEDDY 1996/97

Table 18: Installed Generating Capacity (Utilities only)

	Total capacity (MW)		% Increase
	31.3.94	31.3.93	
Lakshdweep	5.37	5.12	4.88
A & N Islands	29.47	28.39	3.80

Table 19: Gross Energy Generation (Utilities only) in Gwh

	31.3.94	31.3.93	% Increase
Lakshdweep	12.71	11.50	10.52
A & N Islands	68.73	62.22	10.46

Table 20: Installed Generation Capacity (Captive) of Miscellaneous Industries having plant capacity of 1 MW and above

Lakshdweep	0.00
A & N Islands	1284 kW

Table 21: Fuel consumption for electricity generation during 1993-94

	Diesel oil (k lit)	Generation (Gwh)	Average oil consumption (Lit/kWh)
Lakshdweep	3435	12.71	0.27
A & N Islands	19077.36	68.73	0.28

Table 22: Energy sales during 1993-94 (Gwh), categorywise

Island	Total energy sold	Domestic	Commercial	Industrial power (low & medium voltage)	Public lighting	Traction	Agriculture	Public Water Works & Sewarage	Misc.
Lakshdweep	10.36	7.40	1.63	0.70	0.63	0.00	0.00	0.00	0.00
%		71.43	15.73	6.76	6.08				
A & N Islands	51.07	21.46	13.76	5.49	2.25	0.00	0.00	0.13	7.98
%		42.02	26.94	10.75	4.41			0.25	15.63

Source: *Electric Supply, 1993-94, General Review, Central Electricity Authority*

2.2 Electricity Interface Requirements

2.2.1 *Transmission and distribution network in India*

The nominal Extra High Voltage lines in use in India are 400 KV, 230/220 KV, 110 KV and 66 KV. 400 KV lines have been introduced so far by some of the SEBs and Central Sector only.

The standard voltages of operation on the distribution side are 33 KV, 22 KV, 400/230 Volts besides 6.6 KV, 3 3 KV and 2.2 KV. The low voltage system has 3 phase 4 wires giving 400/420 volts between 2 phases and 220/240 volts between phase and neutral. This has been universally adopted in the country.

Tables 23 depicts the length of lines operating at various voltages as on 31 March 1991 with comparative increase over previous year.

Table 23: Transmission and Distribution Network in India [vii]

Voltages	**Length of lines (Ckt. Kms.)**		
	31/3/90	**31/3/91**	**% increase**
400 KV	10360	21634	108 82
230/220 KV	58968	62345	5.73
132/110/90 KV	88366	87965	(-) 0.45
78/66 KV	34594	34947	1.02
33/22 KV	181400	212267	17.02
15/11 KV	1322797	1327810	0.38
6.6/3.3/2.2 KV	1905	1964	3 10
Distribution lines	2709111	2784482	2.78
Total	**4407501**	**4533414**	**2.86**

2.2.2 *Synchronisation with the Grid*

The process of connecting an alternator with another or with common bus is known as synchronization. Generally when alternators are used in a power system they are in parallel with many other alternators. This means that the alternator is connected to a live system of constant voltage and constant frequency. Often the electrical system to which the alternator is connected has already so many alternators and loads that no matter what power is delivered by the in coming alternator, the voltage, and frequency of the system remains same. In such a case, the alternator is said to be connected to infinite bus.

For proper synchronization of alternator, the following three conditions must be satisfied.

1. The terminal voltage of the incoming alternator must be same as bus bar voltage.
2. The speed of the incoming machine must be such that its frequency equals bus-bar frequency.
3. All three phases of the alternator voltage must be identical with the phases of the bus-bar voltage.

If there is mis-match of any of these factors, either on supply or on grid end, the system would trip. The critical issues are as follows (for the supply end first, then the network end):

2.2.2.1 *Supply side characteristics*

Generator

There are essentially two types of alternating current generators, synchronous and asynchronous (induction generators). The choice of the type depends on the characteristics of the grid to which the generator will be connected and also on the generators operational requirements. Synchronous generators are used in case of isolated load networks or wherever the unit has a significant influence on the network In some particular cases asynchronous generators may also be used In case of large networks both types of generators can be used. Before making a decision on the type of generator to be used, it is very important to take into account the following consideration.

1. A synchronous generator can regulate the grid voltage and supply reactive power to the network It can therefore be connected to any type of network.
2. An asynchronous generator has a simpler operation requiring only the use of techo-generator to couple it to the grid. As the machine is coupled to the grid there is a transient voltage drop, and once coupled to grid, the generator absorbs reactive power from it When the power factor needs to be improved, a capacitor bank is necessary. The efficiency of an asynchronous generator is generally lower than synchronous one.

Type of regulation and modes of operation.

If a unit or the plant operates in an isolated network, or is an important part of the network, a governor is required to maintain the network frequency during load changes. If the plant is to operate on a large network which imposes the frequency, its units can be fitted with simplified governors having level feedback or load feed back. Stability may be effected in the case where part of a large grid becomes accidentally detached and simplified governors are used. The components in a power plant are normally designed depending upon the regulatory requirements of the grid

Load sharing

The amount of load taken up by an alternator running in parallel with other machines is solely determined by the power input to its prime mover. Any alteration in its excitation merely changes its kVA output not its kW output which essentially means it merely changes the power factor at which the load is delivered.

2 2 2.2 *Network characteristics*

In this case of interconnections with the grid, the plant is intended to operate with a grid, which imposes the frequency The characteristics of the grid - voltage tolerance, frequency tolerance, short circuit power, (at the point where the new scheme is linked to the grid), output of the largest generator working in the network and the power factor determines the control and protection requirements of the system

The status of the grid decides its suitability to absorb the power generated and fed to it by a solar thermal power station The stability of the grid can not be quantified by a single entity because it is influenced by several factors, either collectively or individually. An acceptable grid stability means minimum grid-caused downtime of the power station. The following are the key factors influencing the grid stability and consequently the performance of the power plant.

Transmission line outage

It is observed that the average frequency of outage increases as voltage level of transmission is reduced from 400 kV to 66 kV. For example, in Gujarat, the annual frequency of downtime per line is 92.62 in case of 66 kV line as compared to 21 for 400 kV line.

Voltage abnormalities

Grid voltage fluctuations and unbalances are common phenomena in power systems. The voltage drop beyond the acceptable limit is very common in Indian grids. The voltage drop may reach as low as (-) 30% which is much beyond the tapping range of transformer (+5 to - 15%). On many occasions it is observed that the power transformers are overloaded and consequently the demand is restricted by disconnecting some lines. Another common feature is the voltage imbalance. During periods when there is high moisture content in the atmosphere, grid imbalances of up to 20% may be experienced.

System frequency

The system frequency is continuously monitored at the load dispatch centre of the state utility. In Gujarat, between April and July, the recorded maximum and minimum instantaneous frequency ranges between 51.21 Hz and 48.07 Hz.

Electrical protection

The connection with the grid and the electrical protection to be provided will depend upon the type of the grid .The connection could be simple isolating switch or a circuit breaker with protection.

2.2.3 Regulatory Requirements

Since both, generation and transmission, is usually handled by the same agency, namely, the state utility, no specific regulations have been framed for the interfacing, except that all the technical requirements should be fully met. There has to be a formal agreement between the generating agency and the utility.

2.2.4 STP plant and grid connection

STP technologies which utilise traditional steam or gas turbine plant (parabolic troughs, central receivers, some dish systems) rely on the normal governing mechanisms to achieve grid synchronisation, as described above.

The quantity and quality of steam entering the turbine is not as controllable in a purely solar system as it is in a fossil-fuel fired power station. Without some storage or back-up firing, occasional interruptions in solar would probably reduce the power available from the turbine to such an extent that the grid conditions could no longer be met, and the grid connection would trip. These conditions would also be experienced during cloudy periods as well as at the end of the day as the level of solar insolation decreases.

From a grid supply management point of view, it is far from ideal to have a generating station which can quite suddenly trip out of the grid with very little prior warning.

2.3 In country manufacturing

The equipment required for a solar thermal power plant can be broadly classified as:

i. Solar steam generating system comprising solar collectors, heliostats, receivers, heat exchanger, tracking system, heat transfer fluid (HTF), storage and tracking systems etc
ii. Power generation equipment comprising steam turbine, Rankine engine, alternator, condenser, boiler, cooling system and controls; and
iii. Auxiliary equipment comprising water softening plant, raw water system, fuel handling system, electrical and grid-interconnection equipments etc.

A recent prefeasibility study for a parabolic dish development in Morocco estimated that domestic works and suppliers could make up 41% of the total costs of the project. Table 24 summarises these results.

Table 24: Cost breakdown for a 80MW$_e$ SEGS plant in Morocco[viii] (all figures in '000 US$)

	Moroccan supply share	Total supply	Moroccan %
Machinery & Equipment	35,121	163,730	21 %
Civil works and erection	58,641	67,516	87 %
TOTAL (inc contingencies)	**103,156**	**254,370**	**41%**

An investigation was conducted on the possibility of manufacturing and supply of STP components within India.

While for the heliostat, good quality float glass mirrors can be manufactured in India, reflectors for either parabolic trough collector or parabolic dish are more complicated and must have very high reflectivity. At present there is no manufacturer in India who can produce low iron content float glass with high reflectivity and minimum specularity. It is reported that reflectivity of glass manufactured in India is around 90% against the requirement of at least 98%. The manufacture of curved mirrors is also a problem.

The Indian Oil company had developed a heat transfer fluid (HTF) which can withstand a maximum temperature of around 250°C. A typical requirement for a STP plant is a HTF capable of attaining a temperature of 400°C.

Similarly, other components like, evacuated tube absorbers for the parabolic trough collectors, the precise tracking system and rotary joints for the dish etc. are such components which can be produced in the country only after the transfer of technology, a lot of upgradation of skills as well as manufacturing processes and a huge investment.

There is no doubt that once the proper technology transfer takes place, these components can be made locally However, the investment required by the private sector would only be financially viable if there was a perceived sustainable market for the components and / or some sort of incentive available. Until the market is sufficiently developed, some importing of specialist components will be required.

All the other equipment required can be either manufactured or procured indigenously. In fact the local equipments like turbines, boilers, alternators, cooling systems and pumps etc.

are at par with any imported equipment An indicative list of probable Indian manufacturers of various items is given in Annex 3. Furthermore, special purpose machines and processes like CNC milling/nibbling/spark erosion machines and molding equipments are readily available within the country itself.

There have been a number of attempts to developed high temperature solar concentrators on a laboratory scale in India. These include:

- Hindustan Brown Boveri parabolic trough development
- Indian Institute of Science parabolic trough development (using imported components)

Both of these developments are described in detail in Section 1. Neither of these two systems have been developed to commercial stage In addition, some development work on manufacturing simpler parabolic trough systems has been carried out at the Indian Institute of Science[ix].

Some mention should be made of solar chimneys and solar ponds, both of which require very few specialist components and particularly well suited to local manufacture. Solar chimneys are manufactured from materials such as glazing, structural supports, corrugated steel sheet, concrete and a wind turbine.

2.4 Operational Economics

In order to carry out economic analysis and for arriving at a comparative picture of various solar thermal electricity generation technologies, a computer model *(in MS-Excel)* has been developed. The analysis is based on *life-cycle costing*, leading to *levelised annual cost* figures.

2.4.1 Technologies

The following generic types of STP plants were studied:

- Parabolic troughs with the following configurations.
  - ⇒ Trough with 100% solar share
  - ⇒ Trough-Natural gas with 25% solar share
  - ⇒ Trough-Natural gas with 60% solar share
  - ⇒ Trough-Fuel oil with 25% solar share
  - ⇒ Trough-Fuel oil with 60% solar share
- Parabolic dish
- Central receiver
- Solar chimney
- Solar pond

For the comparison purpose, the following conventional power plants were also modeled:

- Diesel operated generator
- Natural gas combined cycle plant

2.4.2 Costs

The cost figures are taken from published literature [i, iii, x, xi, xvii, xii, xiii]. As these figures pertain to different plant sizes, there is little uniformity in the plant capacities under comparison. Similarly, there is another limitation with regard to the cost figures. The limitation is that while some figures are based on actual plants, like those for a parabolic trough and solar pond, other figures are mere projections, notable among these are solar chimney and big capacity dishes.

2.4.3 Comparison by mode of operation

For projecting a realistic situation, the plants were divided into two categories, namely: centralized and decentralized systems. Thus plants up to 1 MW capacity are put in decentralized applications and plants having larger capacities than this have been classified under centralized mode. The cost comparisons are listed in Tables 25 and 26.

Table 25: Cost Comparison- Decentralized Applications

Technology	Capacity (MW)	Capacity Utilisation Factor (CUF, %)	Capital cost Million Rs/MW	Levelised cost Rs/kWh
Dish	0.05	28	138	9.87
Dish	1	30	70	4.78
Diesel Generator	0.375	50	20	2.76

Table 26: Cost Comparison- Centralized Applications

Technology	Capacity (MW)	CUF (%)	Capital cost Million Rs./MW	Levelised cost Rs./kWh
Trough	30	25	102	8.28
Trough (25% solar + 75% NG)	40	85	113	3.57
Central Receiver	2	25	320	25.89
Central Receiver	30	25	332	26.80
Central Receiver	100	25	207	16.71
Solar Pond	5	15	73	9.89
Chimney	35	33.7	226	13.54
Chimney	200	33.7	76	4.58
Natural gas combined cycle	86	85	31	1.55

2.4.4 Consideration of Transmission Losses

Taking a pragmatic approach, decentralized electricity cost is compared with delivered cost of power by extending the grid to that remote location The comparison with extending the grid is done by taking lowest cost of conventional power generation @ Rs 1.5/kWh. The assumptions used for calculating the transmission costs are given in Table 27.

Table 27: Computation of transmission cost

Transmission loss	Transmission cost	Extension cost
15% of energy generated	• Capacity cost Rs. 10 million/MW • Load factor 0.8 • Discount rate 12%, 30 years • O&M 2% of capital cost, escalated @ 6% per annum	• 15 km • load factor 0.2 • load 50 kW
Rs. 0.30/kWh	Rs. 0.18/kWh	Rs. 5.50/kWh Sensitivity analysis: • Rs. 3.70 (10 km) • Rs. 2.75 (load factor 0.4) • Rs. 2.73 (100 kW)

Once the transmission costs are added to the conventional power, the levelised costs, in decentralized mode change as follows:

Table 28: Levelised cost of servicing a small isolated load of 50 kW, 15 km from the grid with a load factor of 0.2

Technology	Generation cost Rs/kWh	Transmission cost Rs/kWh	Transmission extension cost Rs/kWh	Delivered cost Rs/kWh
Dish (50 kW)	9.87	0	0	9.87
Dish (1 MW)	4.78	0	0	4.78
Diesel Gen.	2.76	0	0	2.76
Natural gas CC	1.55	0.45	5.50	7.50

2.4.5 Assumptions

The following assumptions / incentives have been made for this analysis of operational costs:

- Inflation rate 6% per annum, real interest rate 6% per annum
- Discount rate 12%, project life 30 years
- O&M and fuel cost escalated at the rate of inflation
- Marginal tax rate 40% + 7.5% surcharge
- 100% depreciation on investment
- 100% exemption from payment of tax on the revenue generated, for a period of 5 years from the commissioning of the plant. After that, there is a tax exemption to the tune of 30% for 5 years, spread over first 12 years. That means that essentially, the full tax liability begins only after 12 years of starting the project
- Low interest rate of 8.3% from IREDA
- 75% of investment as loan from IREDA
- 2 year moratorium
- 8 year loan repayment
- Exemption from Minimum Alternate Tax

2.4.6 Conclusions

The economic analysis indicates that:

- For certain decentralised applications, solar thermal power generated using parabolic dish technologies would be more economically viable than grid extension

- A capital subsidy of 30% would be required to make solar thermal power generation using parabolic dish technologies in a decentralized application competitive with that from a diesel generator

- In centralized, grid-connected mode, although presently the electricity from any of solar thermal technologies is costlier than traditional fossil-fuel sources, parabolic trough-natural gas with 25% solar share appears to be most economically attractive option

2.5 Operation and maintenance issues

Similar to any power plant, the basic objectives of an O&M programme should be as follows[xiv]:

- To maximise periods of operation between inspection and overhauls;
- In-place, on-site inspection and maintenance;
- Use local trade skills to disassemble, inspect and reassemble.

O&M activities on STP plant can be split into the following categories:

- Maintenance (such as washing of mirrors and replacement of broken or defective components)
- Operations (such as control of the power block)
- Administration
- Technical services
- Reserves funds (for unexpected major equipment failures) and insurance costs

Figure 5 indicates how these different elements contribute to the overall O&M costs

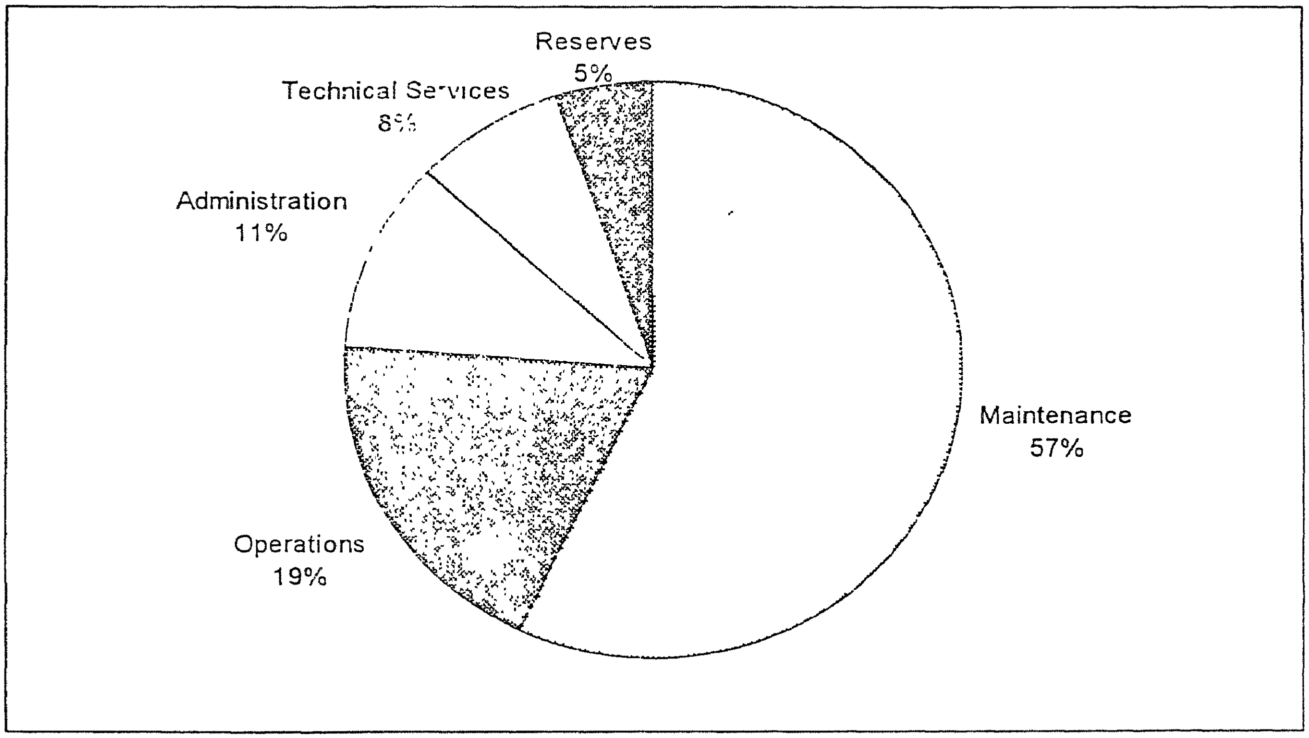

Figure 5: Distribution of O&M costs by Category for a Parabolic Trough plant in USA, with natural gas back-up

The costs of O&M activities can contribute up to 20% of the levelised energy cost from the plant. They depend on the type of back-up fuel chosen. For instance, oil-fired plant will require more elaborate flue gas treatment, and hence higher O&M costs than gas-fired plants. Labour costs and water costs can vary greatly between different countries, and this can particularly effect the total O&M costs

There follows an assessment of O&M issues for the various STP technology options.

2.5.1 *Parabolic Trough Systems*

There have been concerted research efforts carried out in the USA (at the plants in California) on reducing O&M costs, for both the existing parabolic trough systems and new developments. The overall goal of this work has been to develop management methods and technical improvements which will approximately halve O&M contribution to electricity costs in future STP plants. This can be achieved by both reducing the O&M costs, and increasing the electrical output of the plant The following areas have been particularly focused on: [xv, xvi]

- Upgrading control systems (on-line monitoring and optimisation of the power cycle and the interface between the solar field and the power block)
- Reducing maintenance costs through more effective planning and implementation. Maximising availability whilst minimising manpower and material costs.
- Increasing the efficiency and lifetime of the solar field components
- Improving the effectiveness of the power block / solar field interface
- Replacement of solar field flexible hoses with ball joints
- Improved seals for the heat transfer fluid pumps and valves in the solar circuit
- Optimisation of mirror washing Two mirror washing techniques can be employed: Deluge and high pressure. The deluge method is quicker but not as effective as the high pressure method. The optimum programme has been developed whereby a high pressure wash is carried out, followed by a couple of deluge washes at short intervals (a couple of days). During this time, the reflectance of the mirror decreases. After about 2 deluge washes, a high pressure wash is carried out, and this restores the reflectance to the higher figure
- Upgrade of mirror brackets to reduce breakage
- Reduction in fugitive losses of heat transfer fluid
- Improved measurement of the flow of the heat transfer fluid
- Improved collector alignment methods and tracking accuracy.

Several of these improvements could be applied to any STP technology. The following estimates (Table 29) have been made of the potential savings in O&M costs of implementing all of these improvements on a new STP development.

Table 29: Estimated O&M costs for new STP plants

Development	**Approximate O&M costs**
Base case (today's technology)	2.0 US c/kWh
New trough development	1.4 US c/kWh
New central receiver development	1.6 US c/kWh
New Dish / Stirling development	1.7 US c/kWh

2.5.2 *Central Receiver Systems*

Some feasibility work has been carried out on the O&M requirements for a 30 MW_e volumetric central receiver system[xvii]. The staff requirements have been estimated to be as follows:

Operating staff	10
Maintenance staff	13
Administration staff	10
Total staff	**33**

All of these staff would be local trained personnel. Spares to be held on site should include:

- Lubricating oils
- Welding rods
- Valve packings
- Insulation
- Computer boards
- Pump impellers
- Thermocouples

Certain specialist maintenance activities would be carried out by outside contractors, for instance, for the steam turbine overhaul.

2.5.3 Dish Stirling Systems

Some monitoring work has been carried out on three 9 kW dish / stirling systems in Almeria, Spain[xviii]. In particular, the O&M requirements were investigated over a period of 18 months operation. Figure 6 shows the contributions that each component of the system made to the total failures of the system.

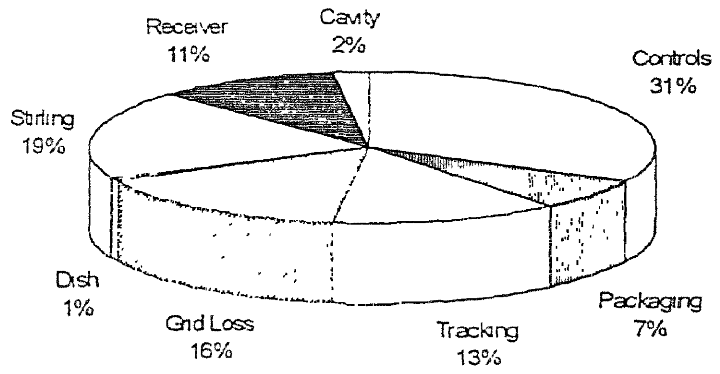

Figure 6: Dish Stirling Failure Statistics

Stirling engine failures were attributable to either the adjustment of the cylinders, or welding defects in the cylinder heads. These manufacturing faults have now been rectified and are not expected to cause further problems Control system failures were caused by defective electrical contacts

As a result of these failures, availability of 70% was achieved over the 18 month period.

2.5.4 Solar Chimney Systems

The lack of delicate mirrors and fewer moving parts will mean that O&M costs for solar chimney systems are likely to be lower than for other STP systems. Indeed, results from a 50 kW prototype system in Spain indicates that the glazed area can be self cleaning if there are occasional rain showers

The main O&M elements are likely to be.

- Associated with the wind turbines;
- Electrical maintenance and checks;
- Maintenance on the glazed area;
- Any maintenance required on the ground under the glazing (for instance, grass cutting)

2.5.5 Solar Pond Systems

The solar pond is a reservoir of water, combining both the collector and storage system. A solar pond can be divided into three zones, namely: (i) upper convective or surface zone, (ii) non-convective or gradient zone and, (iii) lower convective or storage zone. The maintenance and operating procedures, specific to solar pond systems, are as follows:

The proper maintenance of the salinity gradient of the solar pond is essential for its long term and efficient operating. There are mainly two requirements for the gradient maintenance. The first one is to recycle or replace the salt that is continuously diffusing upwards from the high salinity storage zone to the low salinity surface zone. The second requirement is to monitor the salt gradient densities regularly and to carry out corrections for any instabilities that may occur within the gradient zone.

The salt diffuses slowly upwards through the gradient, the rate varying with the ambient conditions, salinity and temperature gradients in the solar pond. During this process, the surface zone becomes more saline and its thickness also increases. This in turn causes the erosion of the gradient zone. The storage zone too loses some of its salt. In order to compensate for these losses, the high salinity water is flushed out from the surface zone and stored in the evaporation pond. Once this attains the required concentration, it is pumped back to the storage zone. If re-concentration process takes too much time on account of either unfavourable atmospheric conditions or inadequate evaporation area, fresh salt needs to be added at the bottom of the pond.

At higher pond temperatures, there are chances of development of small unstable local convective zones within the gradient zone. If internal convective zones are left unattended, their thickness will start growing, affecting the gradient zone itself. Hence it is very important to constantly monitor the gradient and undertake the corrective measures whenever necessary. These corrections can be made by injecting concentrated brine or low salinity water, as the situation demands, at the particular level.

Good brine transparency in the pond is one of the most important factors in achieving good temperature and high efficiency. It is important to keep the gradient zone and surface zone as clear as possible, within economic limits. It is essential to chemically treat the brine on regular basis to limit the growth of algae and bacteria The brine must be in the correct pH range so that the chemicals act effectively. Wind borne debris such as dirt, dust and leaves etc., floating on the pond surface too need to be skimmed out at regular intervals.

2.5.6 Conclusions

The O&M requirements of STP plant can represent up to 20% of the life cycle costs of a STP plant. They can also represent an important source of employment for local personnel A 80 MW parabolic trough plant has been estimated to require about 50 permanent qualified employees, mostly operators, a maintenance group and plant administration [viii].

Previous STP pilot projects have not placed sufficient emphasis on the long term successful operation of the plant. Insufficient support, training and spares have been supplied to enable long term operation.

It is essential that O&M requirements are considered at all stages of the development of a STP project. This is particularly true for developments involving large proportions of imported technology, rather than components that have been manufactured locally. As a minimum, the development must include the following items:

- Adequate training of local operation and maintenance personnel;
- Design and implementation of an methodical operation and maintenance programme;
- Technical support for O&M personnel;
- Supply of sufficient spares. especially of particularly specialist components, which may have a long delivery time;
- Establishment and implementation of an appropriate warehousing programme for maintaining the stock of spares at the site.

In addition, it is important that there are commitments from the suppliers of components that spares will be available for a certain number of years (preferably at least 20).

It is also important to ensure that the project is financially viable throughout its whole operating phase, and to include adequate insurance and reserves in the financial planning. Otherwise, the situation might arise where it is no longer economic to maintain the plant, and it will fall into disuse.

2.6 Criteria for site selection

There are many factors which must be considered when assessing a site for a STP plant. Some of these are technical necessities (such as having stable ground conditions on which to develop the plant). Others are conditions which will ensure that the maximum possible output is achieved from the STP plant

2.6.1 Meteorological conditions

Direct solar insolation at the site should be equal to or greater than 1,900 kWh/m^2 yearly average direct solar radiation[xix].

Consideration should be given to local weather conditions, which may vary considerably from conditions at the nearest meteorological monitoring point Extreme conditions should also be taken into consideration (such as hurricanes and sandstorms), as these will effect the structural loading on the plant

2.6.2 Local site conditions

STP plant should really be sited away from industries which emit large quantities of particulates or other materials into the air. These materials could deposit on the concentrator mirrors, increasing the required frequency of washing. This can be a problem, as it is not uncommon for industries to build up near a power plant. It is a particularly important issue if STP is to be used as captive power generation for an industrial site. For similar reasons, particularly dusty sites are not ideal, as more frequent washing of the mirrors will be required.

The possibility of shading from neighbouring structures must be considered at an early stage. Suitable ground stability is needed for developing plant of this nature, especially for the power block. The suit should also be well drained.

The ground should generally be flat, although there would be some benefit for parabolic trough systems (which track the sun in one dimension only) from having a slight southward slope in the northern hemisphere.

There would be benefits associated with using land which is of little economic value for other purposes. This would negate the risk of STP absorbing land which has been used productively by another industry (such as agriculture). It is unlikely that land occupied by the STP plant could also be used for agricultural purposes.

2.6.3 Infrastructure conditions

For maximum cost effectiveness, the site should be near to the following services:

- The high tension transmission grid;
- The load (excessive transmission distances will increase the losses);
- The backup fuel source (for instance, a natural gas distribution pipeline);
- Road / rail communications

One of the most important resources required for the operation of an STP plant (apart from the sun) is water. In systems that utilise a Rankine cycle turbine, water is often required for condenser (cooling towers), although it is possible (but more expensive) to use dry cooling towers. Water is also required for maintenance activities, particularly for washing the reflective mirrors (see Section 2 5).

There is therefore a balance to be struck between choosing a site with a very high direct solar insolation level (and possibly low rainfall), and the requirement for a water supply at the site and conditions which are not excessively dusty.

2.7 Land use

The low power density of solar energy incident on the earth means that solar power technologies are larger than other power generating technologies, such as fossil-fuel fired power stations[2].

In certain circumstances (such as desert locations), it may be that there are few limitations associated with the land use requirements of STP technologies. However, land use in other locations can be more important, and cannot be ignored.

Some STP plants will be large, MW_e developments which will have a strong visual impact. Land use for power developments can have social impacts, for instance if they result in population displacement. They can also absorb large areas of land which could be used for other economic purposes (such as agriculture)

Some large hydroelectric developments can be seen as examples of developments which have ignored these land use issues, and a great deal of harm has been done as a result. For instance, the Three Gorges Dam project in China will create a reservoir 400 miles long and about 1.2 million people are having to be relocated as a result.

In addition to the social impacts, there are environmental implications. For instance, during the development of the 7th SEGS plant in California in 1988, a one acre knoll containing some endangered plant species had to be "relocated"[xx].

The land use impacts must be considered during any STP development and reduced as far as possible. Obviously ideal locations would be in areas of poor soil quality and low population density. In reality, land use issues will be one of many criteria effecting the choice of site (see Section 2.6)

The land use associated with a STP plant is dictated by the following factors:

- The location of the plant and the solar resource available;
- The design power capacity of the plant;
- The overall conversion efficiency;
- Self shading issues, and the associated ratio of collector area / total area (typically 1:4 for parabolic trough systems [xxi]);
- Land area required by non-collector components, such as the turbo-generator and power block, administration and control buildings, access roads and electrical interconnections

The geometry of the system can also be an issue. Parabolic dish systems linked in parallel (as is proposed for the Australian systems) could be arranged to fit many different shapes of land plots Trough systems must be carefully arranged to minimise pipe runs and ensure balanced flow of heat transfer fluid between the parallel trough runs. This often means that they are rectangular in shape. Solar chimneys and central receiver plants are typically round or hexagonal in shape.

Intuitively, one would expect that parabolic dish technologies would require the least land area (as they typically exhibit the highest conversion efficiencies, and require no ground-mounted power block). Indeed, an investigation of dimensions of installed STP plant and plant still at the design stage indicates this to be true (Figure 7).

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[2] This is not necessarily true if one takes into account areas utilised for mining and transportation of fossil-fuels

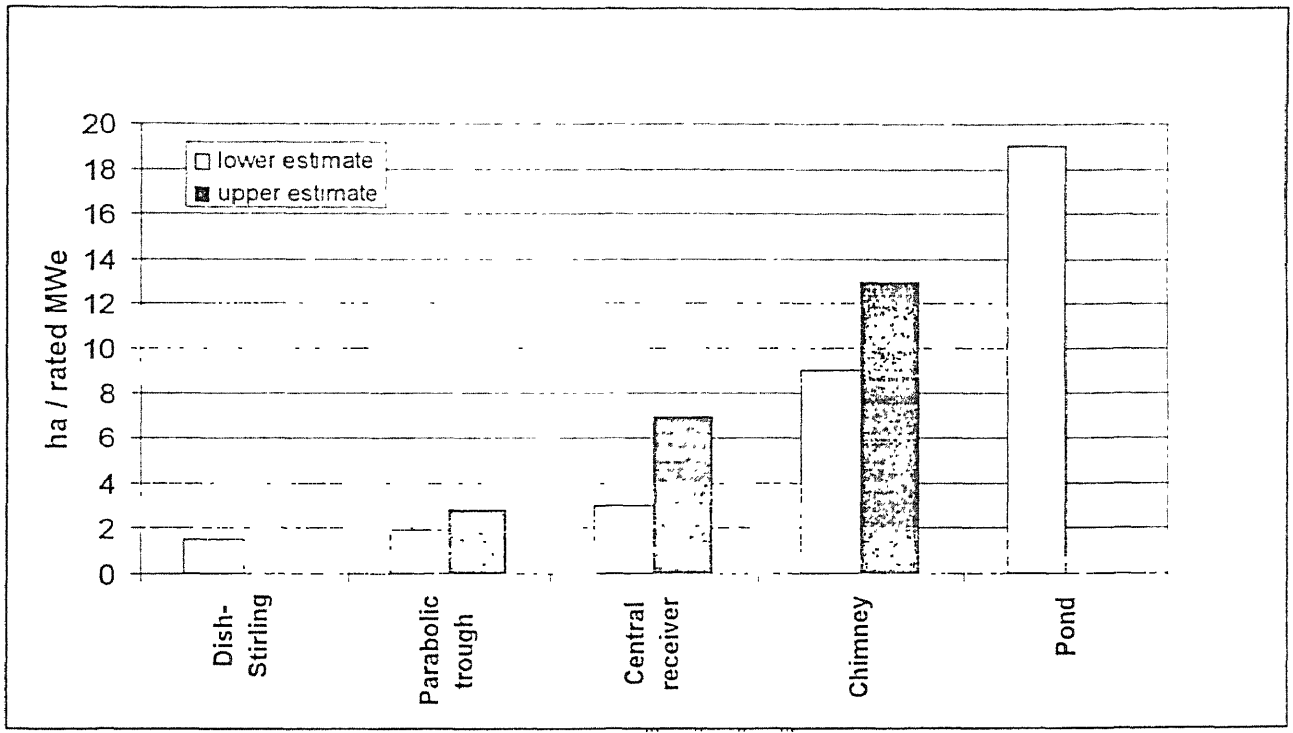

Figure 7: Land use for STP Technologies viii, xvii, xxii, xxiii

To put this in perspective, a recent hydro electric scheme (the Aswan Hydro Project) involved the inundation of 200ha/MW [5] A typical large scale photovoltaic system would require around 4 ha/MW$_p$ land area

2.8 Environmental impacts

2.8.1 Environmental benefits

The main environmental benefits from using STP technologies are similar to all solar and renewable technologies, the main one being the reduction in emissions from fossil-fuel fired power plants. These emissions include

- Greenhouse gases (mainly carbon dioxide)
- Acidic gases (oxides of nitrogen and sulphur)
- Particulates

The nature of the savings of these emissions are different depending on the state of development of the electricity infrastructure In the context of developing countries, and India in particular, there is a shortage of generation capacity. Therefore a STP plant would be constructed instead of a fossil-fuelled power station Therefore the quantity of savings in emissions is related to the type of fossil-fuel the STP is replacing

In India, coal is the most common fuel used in power stations Coal-fired power stations emit more greenhouse gases per unit of electricity generated than either oil or natural gas fired power stations (about 1 1 kg of CO_2 per MWh_e generated). These emissions are compounded by the continued use of old and inefficient generating plant in India, and the poor efficiency of the transmission and distribution grid.

A STP operating with no back-up fuel will emit no greenhouse gases. The same is not true for STP plant operated in hybrid mode, with a fossil-fuel back-up (normally either gas or oil). Emissions in this case will depend upon the configuration of the hybrid system and the solar share The following are two example configurations, SEGS and ISCCS.

SEGS: As with the plants in California, the backup fuel is used to increase the capacity factor of the plant, extending its use into the evening and covering cloudy periods. With a solar share of 75%, greenhouse gas emissions are low.

ISCCS: The proposal for an ISCCS is to incorporate the solar into the bottoming cycle of a combined cycle plant Solar fractions are low (<10%) and therefore greenhouse gas emissions are nearly the same as a conventional CC plant. An additional problem is that the steam turbine needs to be slightly oversized to accommodate the solar contribution This can lead to less efficient operation without solar, and this may negate any benefits gained by using solar.

As indicated above, the greatest emission savings can be realised when the STP plant is replacing coal-fired power. An on-going project in Spain has focused on this point, and is developing a STP system to be installed as part of a refurbishment of an old coal-fired power plant The potential environmental benefits of such a system are high, and, given the large number of old coal-fired power stations in India, such a development would be particularly appropriate for India. Indeed it is understood that a project of this type was in development by the National Thermal Power Corporation (NTPC) in India and KfW a few years ago.

The costs of greenhouse gas (in particular CO_2) avoidance with parabolic trough systems range from about $50 to $195 per ton CO_2 [viii]

2.8.2 *Assessment of potential impacts*

A full life-cycle environmental impact study is outside of the scope of this project Such a study would involve the compilation of a full inventory of impacts at all stages of a STP project, namely:

- Pre-production
- Production of components
- Delivery
- Construction
- Operation
- Decommissioning, disposal / recycling

These impacts could include:

- Resource depletion
- Global warming
- Human toxicity
- Acidification
- Eutrophication
- Photochemical oxidation
- Ecotoxicity

The analysis in this study focused purely on the construction, operation and decommissioning phases of a STP project Also, the study tries to identify particular environmental hazards and does not quantify the impacts on the environment. The following possible impacts have been investigated separately:

- Emissions to air
- Emissions to water
- Emissions to ground
- Ecological impacts
- Noise
- Visual

Table 30 is an introduction to this investigation.

Table 30: Inventory of chemicals used or proposed for various STP systems

STP technology	Materials used or proposed
Parabolic trough	• Synthetic oil heat transfer fluids (biphenyl and diphenyl oxide mixture in SEGS plants) • Water / steam (DISS)
Central receiver	• Potassium and sodium nitrate (Solar 2) • Water (Solar 1) • Air (Phoebus)
Parabolic dish	• Helium, or hydrogen (charge gas for Stirling engine) • Sodium heat pipes (Hyhpire) • Water / steam

Solar chimney	• Air
Solar pond	• Various organic working fluids have been proposed for the *organic Rankine cycle heat engine* (e.g. CFCs, cholorbenzene, thiophene)
Thermal Stores	• Oil (Solar 1) • Salts (KNO_3, KCl, $NaNo_3$)

2.8.2.1 Emissions to water and to the ground

The main materials used in STP power plants that are environmentally hazardous are the synthetic heat transfer oils (HTO). These liquids are used in large quantities in parabolic trough plants. A 30 MW_e plant requires about 380,000 litres [xx]. There is a risk that this material could be spilt at the site, contaminating the soil and possibly migrating into groundwater or nearby surface water.

There are a variety of emission routes which can and do occur. Studies at the operational parabolic trough stations in California have indicated that the most important route results from gross failure of pipework, joints etc. These are generally isolated and repaired immediately, but about 0.9% by mass of the HTO is lost by this route every year. Another emission route is by small, gradual leaks, and these contribute losses of about 0.1% by mass per year.

Some HTOs need complete replacement after about 5 years, and this process represents a hazard, due to the movement of large quantities of the oils around the site.

2.8.2.2 Emissions to air

The main emissions to air from STP plants would be of water and steam from any wet cooling towers (only necessary if a Rankine cycle is used).

The synthetic heat transfer oils used in parabolic trough systems do gradually decompose with time. The decomposition products (primarily benzene, phenol and toluene) are vented from the system about twice weekly. About 0.03% of the HTO is lost by this route per year. A condenser could be used to trap these vapours.

Various charge gases have used with Stirling engines. The most popular seems to be helium, although hydrogen has also been used. There are no direct impacts on the environment associated with the release of these gases.

Some development work has been carried out (mostly many years ago) on the use of organic liquids in a Rankine cycle turbine. Much lower temperatures could be utilised to drive this process, and non-concentrating technologies could be used (such as solar ponds). Unfortunately, many of the most appropriate fluids are either environmentally hazardous (such as CFCs) or represent a safety risk (e.g. are extremely flammable).

2.8.2.3 Ecological impacts

STP impacts on local ecology are mostly associated with the size of the developments, and as such are dealt with in Section 2.7.

2.8.2.4 Noise

There are no particular noise issues associated with operating STP plant. Indeed, as there is no requirement for constant delivery of fuels (as there would be for a coal-fired power station), noise is likely to be less of a problem.

2.8.2 5 Visual

As mentioned in Section 2.7, STP plant do often cover large areas of land. Central receiver plant, and in particular solar chimneys, would be more visually intrusive, as they require tall towers. The tower for the absorber on a central receiver plant could be 130m high [xvii].

A 200 MW_e solar chimney would be around 1 km high This would be very visually intrusive, and would be visible for many miles around In addition, it is likely that the chimney would be required to be fitted with identification lights, in the interests of aircraft safety at night

2.8.2.6 Other Impacts

An impact that warrants discussion is the requirement for water at an STP plant. All concentrating technologies require water for cleaning of the mirrors (this is discussed in more detail in Section 2.5). A more major demand for water would come from the use of wet cooling towers. A Case Study of a proposed 80 MW_e parabolic trough development in Morocco estimated the following water demands·

With wet cooling tower	1.5 million m^3/year
With dry cooling tower	0.32 million m^3/year

Solar ponds need water supplies to replace evaporated water. There is a proposal to use water sprays at the top of solar chimneys to increase the air flows across the wind turbine

The balance between solar resource and water supplies has been discussed in Section 2.6 The impact of this demand for water could be as much social as environmental, as the draining of surface or groundwater supplies could effect water supplies downstream.

2.9 Safety issues

Any STP project must comply with all of the safety legislation that is applicable in the particular country of development These could include regulations governing operations at power plants, pressure vessels, construction activities, design of structures, and general industrial activities.

There are particular safety considerations for STP technologies Many of these will be covered by the requirements of the above legislation, or by the need to restrict entry to the site for security reasons

General

- The large quantities of glass at a STP plant warrant close attention to the structural supports. It must be ensured that the glass components are secure under all possible weather conditions
- The nature of most STP plants means that some very hot surfaces cannot be fitted with guards. Maintenance activities should therefore be carefully scheduled so that all elements have had sufficient time to cool before maintenance is carried out
- Fail-safe controls must be installed so that, in the event of a failure of the heat transfer fluid pump, the absorber does not overheat Alternatively, all components in the solar circuit must be designed to be able to withstand these "stagnation" temperatures.

Parabolic Trough

- These systems require the use of long pipe runs of heat transfer fluid (normally an oil) circulating at pressure at temperatures of up to 400 °C. Hazards associated with this are gross failure of a pipe and human contact with the hot oil. If an ignition source is present, there could also be the potential for a fire and explosion hazard. Ways to reduce the risks include careful design of the pipework to avoid gross failures; regular inspection of the pipework for leaks; restricting access to the solar field to non-operational periods only.

Central Receiver

- A potential hazard with these systems is the shifting of the focus point off the absorber. If the focus point is on part of the support structure for the absorber, the supports could be damaged. Conceivably, the focus point could shift onto combustible materials, or even onto personnel working at the site Ways to reduce these risks include fail-safe heliostat control systems.

Parabolic Dish-Stirling

- There is some on-going research on the use of an innovative heat pipe receiver for use with dish-stirling systems. This heat pipe uses sodium as the working material. This is a hazardous material, and appropriate safety procedures must be implemented.

Solar Chimney

- The structural safety of a solar chimney must be assured. A large chimney plant (200 MW_e) would require a chimney 1km in height. There is currently no man-made structure of this height, and there is therefore some uncertainly as to the safety of such a structure.

Solar Pond

- A hazard associated with solar ponds would be personnel falling into the pond during operation. The risk of this occurrence can be minimised by restricting access near the pond surface.

2.10 Decommissioning Issues

When planning large power developments, it is prudent to include some consideration of the decommissioning issues when the plant reaches the end of its operational lifetime. Making provisions for decommissioning at the start of a project can save time and money in the long run.

In the context of India and the chronic shortage of electricity generating capacity, decommissioning of power plant is rarely considered. Instead, components are repaired and the power plant maintained operational well past their design lifetime. This has, at least in part, contributed to the situation today where the electricity network as a whole operates at low efficiencies and low capacity factors

Many of the decommissioning issues relevant to STP plant are the same as for any power plant. For instance, both involve large volumes of steel and concrete (both for structural support and incorporated in active components). These materials have to be dismantled in a safe manner and removed from the site, either for reuse, recycling or disposal (most of these materials will be inert waste).

The volume of glass at a STP station will be large. This presents added complications for decommissioning. From a safety point of view, the glass should be removed whole and not destroyed on site. This could be a laborious and expensive process if provisions are not made in the design of the glass mounting systems

The large volumes of heat transfer oils circulating on some STP plants also need to be handled carefully. The systems will have to be carefully drained prior to dismantling, and provisions should be made for preventing fugitive emissions of oils.

Solar ponds present their own unique problems when it comes to decommissioning, as filling in the large areas of pond could be very expensive. The alternative is to leave the ponds in place, however this may effectively preclude the use of the land for any other purpose.

3. Institutional Assessment

3.1 Introduction

In order to fully understand the institutional infrastructure that STP technologies will operate within, the following sectors have been investigated:

- The existing electricity infrastructure in India;
- Rural electrification in India;
- The Independent Power Project structure in general and in India particularly[3].

In terms of the institutional aspects, STP technologies have more in common with large hydroelectric schemes that with other solar technologies Technologies such as photovoltaics are well suited to low demand / power applications in rural areas. Most STP technologies are best suited to large kW / MW developments As a result, the scale of financing needed is much larger and more concentrated, as with large hydro schemes. The development structure of large hydro electric technologies has therefore also be investigated.

The lack of any completed, benchmark STP projects in Asia means that any assessment of the institutional issues must involve a certain degree of extrapolation from experiences in other sectors. Hence the above investigation is general in nature, covering all relevant power technologies.

With this background information in mind, an attempt is then made to extrapolate to future STP developments. and the roles of the various institutional players are predicted. An extrapolation of this kind makes certain assumptions about the way the market for these technologies will develop in the future These assumptions are set out and justified in a Development Scenario for STP technologies.

3.2 The Electricity Industry in India

3.2.1 *Key players*

Table 31 is a summary of the Key Players in the electricity industry in India.

3.2.2 *Traditional Structure*

There is a tradition of state ownership in the electricity industry in India. The Indian Energy Supply Act of 1948 established the State Electricity Boards (SEBs, part of the State Governments) to develop the power sector at the state level, and the Central Electricity Authority (CEA) to develop and co-ordinate national power policy Of the currently installed capacity, 96 % is under public utilities (69 % SEBs and 27% CEA). The National Thermal Power Corporation (NTPC, central government owned) has also been involved in power developments

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[3] There is an increasing tendency to look towards private financiers and Independent Power Projects (IPPs) for STP developments. This is in keeping with the trend for all large power projects, both in developing and developed countries.

Table 31: Key players in the Electricity Industry in India

Organisation	Description
Central government level	
Central Electricity Authority	Administers the policy concerning the control and utilisation of national power resources. They conduct techno-economic appraisals of project reports for new generation plant and issue the clearances
National Thermal Power Corporation (NTPC)	Responsible for construction and operation of thermal power plants, and distribution of power in the Central sector
Rural Electrification Corporation (REC)	To date, REC has implemented most of its activities through the SEBs
Ministry of Environment (MoE)	Issue environmental clearances for any new power plant
Department of Economic Affairs	Involved in the financial side of any power project
Ministry for Non-conventional Energy Sources (MNES)	Ministry in the central government, overall responsibility for renewable energies Activities include resource assessment, R&D, demonstration extension and production Programmes are implemented mostly at State level through State EDAs and SEBs (see below)
Indian Renewable Energy Development Agency (IREDA)	The financing arm of MNES, IREDA focuses on commercialisation of renewable energies
State government level	
State electricity boards (SEB)	Electricity utilities such as Rajasthan SEB Generate, transmit and distribute electricity within their state (in co-operation with any generating companies)
Energy Development Agencies (EDA)	such as Rajasthan Energy Development Agency (REDA). Activities include the development of renewable energies in their state
Non-Governmental	
Licensee	A party granted a licence by the State Government to supply electricity in any specified area
Industrial Credit and Investment Corporation of India Ltd. (ICICI)	Development bank handling public and private funds
Industrial Development Bank of India	
Power Finance Corporation	
Public Sector Banks	

3.2.3 Reforms in the India Electricity Industry

In 1991, the Indian government initiated a series of reforms in the areas of deregulation, trade barriers, tax policies and private sector investment[xxiv]. These opened up the Indian Electricity Industry and started attracting private investors to finance the development of new capacity.

In the new scenario for increasing availability of electricity, apart from usual blend of thermal, hydel and nuclear sources, emphasis is also being laid on renewable energy sources. Until recently, development of this sector has been primarily the responsibility of the Government with relatively small contribution from private sector. However, considering the large requirements of funds for the sector, it may not be possible to mobilize adequate financial resources by government alone. Thus, to mobilize additional resources for the sector to help bridge the gap in demand and supply, the government is encouraging greater investment by private enterprises in the electricity sector.

3.2.4 *Energy Policy*

The energy policy of the Government of India aims at ensuring adequate energy supplies at a minimum cost, achieving self-sufficiency in energy supplies and protecting the environment from the adverse impact of utilizing energy resources Its other main objective is development and exploitation of renewable energy sources, with an emphasis on meeting the energy demands of rural regions. In response to the new economic realities, the government formulated a policy in 1991 to encourage greater investment by the private sector in the power field. This legislation allows private investors or Independent Power Producers (IPPs) to set up generating companies. These IPPs would supply bulk power either to the grid or directly to consumers with the consent of the State Governments

The new policy permits 100% foreign owned companies to set up power projects and repatriate profits without any export obligations Such power projects can be based on any type fuel such as coal, lignite, gas, hydel, liquid fuels, wind or solar The policy allows liberal capital structuring and an attractive rate of return. A two-part tariff structure was provided through a notification in March, 1992. This allowed recovery of full fixed charges with up to 16% return on equity at specified plant load/availability factor This was further modified in January, 1994, August, 1994; January, 1995 and November, 1995 making the policy more flexible and attractive.

In 1991, the Investment Promotion Cell (IPC) was set up under the Ministry of Power. IPC is a nodal agency to provide information and assistance to prospective IPPs. It also provides guidance on the clearances to be obtained and the modalities for obtaining them. It facilitates speedy clearances by being the single reference agency.

The policy of the Government of India offers virtually all areas of power production and supply to private entrepreneurs for investment, be it power generation, distribution, Renovation and Modernization or co-generation. The broad features of the Private Power Policy of the Government of India are set out in Annex 4, as well as the number of clearances required for any power development

3.2.5 *State Electricity Boards (SEBs)*

A critical problem in the power sector is the poor commercial performance of the SEBs. This is partly due to the tariffs, which are set by the government. Table 32 is a summary of sales of electricity by sector and the tariff charged The low agricultural tariff is an attempt to encourage the use of electricity over diesel engines in agricultural areas, based on environmental considerations (incidentally, diesel is also subsidised in India).

Table 32: Electricity sales by sector in India and associated tariffs[xxv]

Sector	% of sales	Tariff charged (paise/kWh)	Tariff charged (USc/kWh)
Industrial	36 1	218.4	6.2
Agricultural	28.0	24.5	0.7
Domestic	16.9	91.8	2.6
Commercial	4.6	208.1	5.9
Railways	2 0	254.5	7.3
Outside state	1 8	112.4	3.2
Other	10 6	132.8	3.8

Given that the cost of generating power from thermal sources in India is around 2Rp/kWh (5 7USc/kWh)[xxvi], and PPA are being negotiated for 2.4 Rp/kWh, it is clear the SEBs are carrying a heavy financial burden, mostly attributable to the low agricultural tariff. Commercial losses of SEBs in 1995-96 were a little over Rs.7,500 crore (2 billion US$).

Restructuring of the electricity industry is underway throughout India, with the SEBs being split up, often into three separate entities in charge of generation, T&D, and an independent regulator. The World Bank has been involved in this restructuring process.

3.2.6 Rural Electrification in India

Rural electrification in India is implemented primarily by the State Electricity Boards (SEBs) with financing made available by the Rural Electrification Corporation (REC), a division of the central government and based in New Delhi. REC receives funds from the central government. They then lend funds to SEBs to implement grid extension projects. REC has set targets for the number of villages to be electrified, but the exact choice of villages has been left up to the SEBs.

The Ministry of Power is the core ministry for rural electrification. Any project involved renewable energy sources would be the responsibility of MNES

To date, all rural electrification programmes have involved grid extension, sometimes at very high cost. These programmes have resulted in over 88% of villages now being connected to grid electricity supplies[xxvii]. However, the villages so far electrified have been those that were nearest to the grid The remaining 80,000 villages are the most remote with sparse population density (less than 500 people). They are therefore the most expensive to grid connect.

An investigation of the nature of the remaining non-grid villages was carried out, and the results are presented in Table 33 It is estimated that there are about 18,000 inhabited villages are prime candidates for decentralised power plants.

The REC has started to show some interest in using decentralised, stand-alone systems for electrifying these villages They have recently set up an appraisal division to investigate the options for decentralised systems There is particular interest in hybrid systems (perhaps solar / diesel hybrids) and mini-grids which can, at some stage in the future, be connected to the main national grid.

The REC are also showing some interest in attracting private finance to decentralised power supplies, although distribution and transmission lines would still be owned by the SEBs under current legislation They are currently drawing up guidelines for private involvement.

The REC's first priority is to assess the exact number of villages still without electricity. They then plan to assess different supply options and install some pilot systems. They will then produce guidelines on the optimum solutions for different situations. They are currently searching for overseas funding to carry out these activities.

Interestingly, the REC's experience is that villagers themselves say that they prefer gird connection to decentralised supplies, as the grid is perceived as more reliable. However, in practice, the grid is not very reliable (see Section 2.1), and, during periods of power shortages, the SEB tends to favour the urban areas, leaving rural areas with "brown-out" or "black-out" conditions.

Table 33: Rural Electrification in India (Population Groupwise)

Village classification by population group	Total no. of villages (1981 census)	Electrified as on 31/3 94 as per 1981 census	%	Elecfd. as on 31/3/96 (projections)*	%	Remaining villages as per 1981 census	% remaining
Below 500	283,067	235,268 @	83	237,898 @	84	45,169	16
500-999	141,878	124,659	88	126,557	88	15,321	11
1,000-1,999	97,498	84,166	86	85,684	88	11,814	12
2,000-4,999	47,626	41,521	87	42,660	89	4,966	10
5,000-9,999	7,228	6,770	94	7,150	99	78	1
>10,000	1,835	1,807	99	1,835	100	0	0
All	**579,132**	**494,191**	**85**	**501,784**	**87**	**77,348**	**13**
	583,003 +					80,074 **	

As per "General Review" of Central Electricity Authority (CEA) (1993-94) based on 1981 Census. Data as per 1991 Census is under compilation

* Based on projection made by the author (CEA has reported electrification of 501,784 villages as on 31/3/1996

+ This figure includes Tripura State's 1971 Census figures of 4,727 villages even though there are only 856 villages as per 1981 Census.

@ Includes 1,792 non-census villages reported electrified in Assam

** Taking into account 1,151 non-feasible villages left under 100% States/UTs and 6 villages excess reported by Mizoram net villages to be electrified comes to 80,074 as per 1981 Census.

3.2.7 *Captive Power*

Indian companies are in dire need of a more reliable and efficient power than is currently offered by the grid. States were recently obliged by the GOI to produce guidelines for private generators, including renewable energy generators These included provision for 'banking' power (generating electricity and exporting to the grid with a guarantee that the electricity can be imported at another time), and 'wheeling' power (generating power at one location and using it at another). Banking or Wheeling techniques are currently widely used for wind turbine generated electricity

3.3 Independent Power Projects (IPPs) in Developing Countries

Faced with serious capacity and energy shortages, and insufficient public resources, many countries, including Colombia, China, Guatemala, India, Indonesia, Malaysia, Pakistan and the Philippines[xxviii], are turning to private investors to expand electricity supply. This is in common with most infrastructure projects in this region[4].

IPPs are typically limited-liability, investor-owned enterprises that generate electricity either for bulk sale to an electricity utility, or for retail sale to industrial or other customers. The design of an IPP differs according to the ownership structure of the project. Typical ownership structures include BOO (build, own, operate); BOOT (build, own, operate, transfer) and BLT (build, lease, transfer).

IPPs can be negotiated either through competitive bidding, or through single offers or tenders Competitive bidding has been shown to produce better prices in the USA, but this is often dependent on factors such as reliable fuel markets and access to credit markets.

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[4] Private sources now account for almost three-quarters of all net capital flows to developing countries.

On the other hand, a motivated power developer who is confident they will eventually sign a contract on a single offer basis can make the power project happen in difficult circumstances (for instance, if this is the first IPP in the particular country).

IPPs normally involve a fairly complex set of contractual agreements, including:

- The authority to build the plant;
- A Power Purchase Agreement (PPA) with the utility or consumer,
- Fuel purchase agreements,
- Guarantee agreements (for project completion, country risk etc.).

3.3.1 Financing IPPs

IPPs are usually financed on a "project finance" basis. Companies carrying out IPP projects are often established expressly for this purpose, and they therefore have no track record to support their request for financing Lenders and investors therefore look to anticipated cash flow of the project for guarantees of repayment and returns. The project's assets, contracts and cash flow are used as collateral in the event of default Lenders therefore focus their credit analysis on an assessment of the risks of the project itself Project financing can be more risky to lenders than corporate financing, because the risks are less diversified.

Project sponsors attempt to maximise the level of debt for a project The amount of equity required depends on the lender's perceived risk for the project, and is typically 25 to 35 % in developing countries. Equity can come from the sponsor, or from other project parties or bilateral or multilateral investment agencies (such as the IFC).

The balance of project costs come from loans, the sources of which could be:

- Export credit agencies,
- Bilateral and multi-lateral lending agencies,
- Commercial banks.

Some multilaterals (such as IFC) can mobilise financing from commercial banks through loan syndications

Project finance packages require a carefully selection of lender's debt and sponsor's equity so that the income earned by the completed project is sufficient to service the debt.

The following four fossil-fuel IPP developments are included as examples, and they actually illustrate some of the problems which can occur with these types of developments.

3.3.1.1 Paguthan, Gujarat

Background: 655 MW combined cycle project, using natural gas or naphtha. Due to close deal mid-1996, on-line October 1999.

Developer: Project company Gujarat Torrent Energy Corp. (GTEC). Partners are Siemens, PowerGen, the Torrent Group (an Indian company), and Gujarat Power Corp Ltd (a wholly owned subsidiary of the Gujarat SEB).

Financial: Debt to equity ratio 30:70

			Million $
Debt			468
Equity total			242
Equity partners	Torrent group	30%	
	PowerGen	20%	
	Gujarat Power	12%	
	Siemens	10%	

Remaining 20% equity to be floated on the public market

Turnkey contractor: Siemens

O&M: PowerGen

3.3.1.2 Paiton II, Indonesia

Background: 1,220 MW coal fired plant in eastern Java
Financial closure March 1996

Developer: Project company is PT Jawa Power, which takes its equity from:

Siemens Power Ventures GmbH	50%
PowerGen	35%
PT Bumipertiwi Tatapradipta, Indonesia	15%

Financial: Total cost $1.7 billion
Debt from a variety of commercial and institutional banks.

PPA: PT PLN (state utility) contracted for 30 years

3.3.1.3 *Jegurupadu, Andhra Pradesh*

Background: This combined cycle plant will be one of the first IPP projects to come on line in India 3 gas turbines, 1 steam turbine

Developer: GVK Industries

Financial:

		Million $
Debt.		165
Life Insurance Corp, India	95	
Nordic Investment Bank	70	
Equity		72
GVK	27%	
Asian Infrastructure fund	30%	
CMS Generation USA	19%	
IFC	10%	
ABB	5%	
APSEB	10%	
Total Cost		237

Indian financial institutions involved:
Industrial development bank of India
ICICI;
Former Shipping Credit and Investment Corporation of India
Industrial Reconstruction Bank of India.

Power sold at levelised tariff of 6 UScents/kWh.
Government guidelines cap insurance premium at 1% of capital cost and O&M expenses at 2%.

Problems and delays: Finance ministry delayed the counter guarantee clearance, delaying release of funds by IFC

Poor financial position of SEB, as 43% of power sales are to the agricultural sector at the highly subsidised rate of 0 6 c/kWh.

Lack of fool-proof fuel supply contract from Gas Authority of India has lead to GVK accepting fuel risk.

Shortage of gas has resulted in one of the turbines having to fire naphtha (twice the price of gas).

3.3.1.4 *The ENRON IPP, Maharashtra*

Background

- Maharashtra's peaking demand estimated to be 11,272 MW by 1999-2000. There would be likely shortfall of 22.7% (peak)
- For government target of 5000 MW additional capacity would require Rs 22,000 crore ($6286 millions). Hence the idea of inviting IPPs
- ENRON was one of eight fast track projects and was first IPP to come to India
- No global tenders were floated but route of direct negotiations and Memorandum of Understanding (MoU) was followed
- ENRON offered to build, on BOOT basis, gas based plant of 2,015 MW capacity but Maharashtra State Electricity board (MSEB) got it divided into two phases viz. Phase I and II of 695 MW and 1320 MW respectively

- ENRON Power Corporation promoted Dabhol Power Corp. (DPC) in which G.E, Bechtel and Bank of America will hold $600 million equity with ENRON

Technical details

- Phase I to have liquid fuel (High Speed Diesel or Naptha) whereas Phase II will have LNG as a fuel.
- Combines gas cycle project
- LNG to be imported from Oman by ships at dedicated port at site
- To have Regasification plant
- PLF of 90% with an option to increase it to 95%

Economics

Total cost (Phase I & II)	$2,829 million
Cost (inclusive of infrastructure etc) of Phase I	$919 8 million
Cost of exportable power of DPC at 1997 prices	Rs. 4.19 crore/MW
Cost of exportable power of NTPC gas based plant	Rs. 4.73 crore/MW (Rs. 3.64 crore/MW in 1994)
Cost of plant, equipment and infrastructure constitutes	65% of the total cost
Tariff *(worked out in $ terms)* in 1997	**Rs. 2.40/kWh**
Fixed component	Rs. 1.22/kWh
Variable component	Rs. 1.18/kWh

Financial

⇒ 30% equity (entirely foreign) divided as follows: 80% ENRON
10% GE (main equipment supplier)
10% Bechtel (main contractors)

⇒ 70% as loans from Exim Bank of US, IFC and Indian FIs (Industrial Development Bank of India along with three other banks to provide Rs 600 crore)

⇒ Overseas Private Investment Corporation of US approved $100 million for the project

⇒ Central government guaranteed a return of 16% on equity at 68.5% Load Factor (PLF) and additional 0.7% for each point increase in PLF

⇒ Power Purchase Agreement (PPA) with MSEB MSEB committed to buy power generated at 90% PLF. DPC to pay penalties if

⇒ Delay in implementation schedule

⇒ Failure to maintain guaranteed PLF of 90%

⇒ Counter guarantee from Central government against SEB's failure to honour PPA. The deal, involving Central and state governments and MSEB, is estimated to have provided an insurance cover of Rs. 10-15 billions to the promoters for loan raised from overseas market

With the change of state government in 1995, the deal was re-scrutinised and re-negotiated. The re-negotiated deal has the following features:

- Total project capacity increased by 355 MW. Thus Phase I capacity increased to 740 MW
- Total project cost was reduced by $330 million

- Regasification plant was delinked from the project and its cost is not included in the project cost
- Cost of exportable power reduces from Rs 4.19 Crore/MW to Rs. 3.66 Crore/MW
- MSEB has an option to have 30% of the equity
- Fixed component of the tariff brought down from Rs. 1.22 to Rs 0.70/kWh
- Variable component remains unchanged
- Ceiling placed on levelised tariff of Rs 1 89/kWh whereby any increase over this has to be absorbed by DPC This levelised tariff is envisaged only after Phase II goes on stream (year 2001) Tariff for Phase 1 is to be Rs 2.03/kWh (to be commissioned by 1998)
- Tariff fixed at 1995 base at $1=Rs 32 Actual tariff to work out as per exchange rate
- PLF allowed to be increased from 90 to 95%
- No counter-guarantee for Phase II

After all this, some public interest litigation came up before Bombay High Court which stayed all the activities till that was disposed off It was dismissed in November 1996, but the delay has prompted ENRON to ask for cost revision for the Phase I, to about $1 billion.

3.3.2 Guarantees and risks

Non-recourse financing of IPPs (when lenders agree to rely on the expected revenue streams for repayment of their principle and interest, with no other guarantees from the project sponsors or the host government) is rare Most lenders rely on limited-recourse financing, seeking guarantees from other parties, such as the project sponsors (equity holders) In some projects, lenders rely on the project sponsor's balance sheet and cash flows for repayment (Corporate financing)

Depending on the financial status of the utility, lenders may require guarantees. These may be just the "comfort factor" of having a bilateral or multilateral institution involved. Alternatively, a specific guarantee package may be required (for example, the Multilateral investment Guarantee Agency's investment insurance).

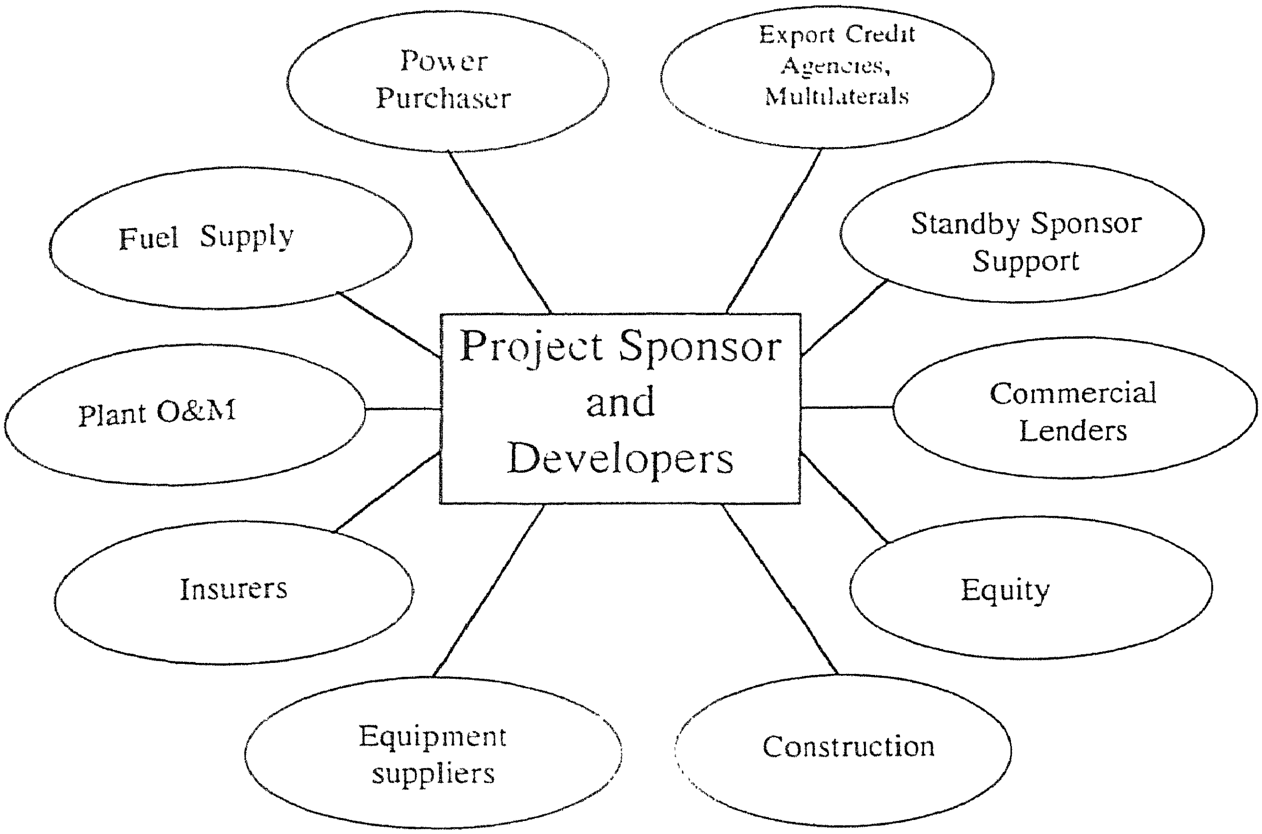
Lenders nearly always seek central government counter-guarantees to back up adherence to the terms of the PPA and to cover the perceived "country risk". For instance, in India, State Governments guarantee SEB payments, but since neither the SEB nor the state government have an international credit rating, a counter guarantee is normally required from the central government.

Central governments are becoming less keen to offer such guarantees, and other methods of covering the "country risk" are being developed. One of these is macroeconomic reform of the power sector, often supported by the World Bank. This involves any of the following:

- Encouraging commercialisation and corporatisation of power utilities, making power utilities more creditworthy;
- Encourage entry of private investors;
- Removal of barriers to entry for new players, eliminating statutory monopolies for public sector power utilities;
- Encouraging regulation that is both transparent and open.

Risk allocation is another important part of any IPP project Each party involved needs to understand the risks they are assuming, and be compensated for these. Figure 8 is a summary of the different risk sharing parties in a power project

Figure 8: Risk Sharing Parties



The highest financial risk exposure in the life of an infrastructure project is during the construction stage, because of the possibility of abandonment, cost overruns etc. The following is a summary of the stages of risk and the financial elements which are employed at each stage[xxix]:

Table 34: IPP Risks and financial elements employed

Stage	Risk level	Financial element
Project development	Very high risk	Sponsor equity capital only
Construction and [illegible]	High risk	A mixture of equity, debt and [illegible]
Operational phase	Low risk	Possibly refinancing with long-term bonds

To secure long term debt placements with private lenders or investors, a project must undergo a rating by a qualified credit rating agency These ratings measure the relative risk that a debt issuer will miss payments over the life of a rated debt security. Ratings range from investment grade (high-quality, suitable projects) to speculative grade (low quality, high risk projects). Risk factors considered relate to the credit quality of the projects participants, and to the project's political, regulatory, legal, economic, technology and structural characteristics.

Investment grade projects allow access to competitive, fixed rate financing and allow the timescale of the debt to be stretched to match the useful life of the project. They can also open access to capital markets Lower ratings can still be acceptable, but lenders will require higher yields

To improve the credit rating of a project, the following measures can be taken concerning the construction stage[xxix]:

- Conceptual design should attempt to limit construction risk;
- Construction management plan must set the budget limits;
- Allocation of the construction risks to the parties best able to manage them i.e. the construction contractors and vendors

Construction and vendor experience, and the management and control of construction funds will also effect the credit rating

3.3.3 *Problems in implementation of IPPs*

The following is a summary of some of the problems that can be encountered with IPP projects. Illustrations of these problems can be seen in the examples in Sections 3.3.1.3 and 3.3.1.4.

Government policy

- lack of commitment,
- ambiguous policies,
- failure to address underlying lack of creditworthiness of the power purchasers,
- insecure fuel delivery,
- restriction on repatriation of profits and currency exchange

Risk allocation disagreements between the different parties involved in the development

As a result of these problems, the following general lessons have been learnt:

- Ensure political commitment.
- Start small;
- Mitigate construction risks;
- Involving local capital reduces political risks;
- Learn from previous IPPs in that country,
- Ensure that the project is financially sound

3.3.4 *IPP Progress in India*

Despite the recent reforms, private power makes up only 4% of installed capacity today in India. This does not seem to be due to lack of interest. The Ministry of Power recorded about 100 GW of proposals in 1995. The following problems are being encountered in realising IPP projects:

- The number of clearances required (see Annex 4);
- Failure to receive clearances;
- Lack of expertise from the IPP developer;
- Problems with fuel availability and transportation increasing risks;

- The highly subsidised tariffs, T&D losses, theft and collection irregularities result in large financial losses from most SEBs. Thus SEBs have difficulties honouring PPAs, and they are not generally creditworthy. Counter-guarantees are often required by Central Government

Eight IPP projects in India have been designated as 'fast track' by the government, and counter-guarantees have been agreed in principle for these developments. However, the central government has made it clear that no further counter guarantees will be offered, and so future IPPs will have to look to other options (such as World Bank guarantees).

3.3.5 Hydroelectric Schemes

Traditionally, large hydroelectric developments have been financed predominantly from publicly supplied or guaranteed funding During the last three decades, the World Bank has financed about 110 hydroelectric power projects in 50 developing countries, ranging from 6 6 MW to 2,460 MW[xxx].

However, the private sector has shown an increased interest in funding hydroelectric projects in the last few years.

Hydroelectric schemes reach realisation when they are both feasible and financible i.e. the least-cost option with a reasonable level of risk

Typical concerns with hydroelectric schemes in developing countries are:

- Population displacement;
- Loss of large areas of valuable land,
- Hydrological uncertainty,
- Construction cost overruns (averaging 30% for World Bank hydro projects)
- Schedule slippage;
- Power demand uncertainty,
- Macroeconomic problems associated with the commitment of large amounts of public finances.

These risks must be managed and mitigated if a potential hydroelectric project is to reach realisation.

Don Pedro Hydropower plant

Background:	16MW Costa Rican power project closed in June 1995, currently under construction and due to go on-line in late 1996.	
Sponsor:	A special purpose corporation PH Don Pedro SA (whose equity investors are the US firms Energia Global Inc. and Energy Investors Funds) and the national utility, Energia Global de Costa Rica.	
Financial:	Financed on a non-recourse basis. The project is rated as non-investment grade. Legal restrictions capping foreign investment at no more than 35 % required structuring a financial package with a 84:16 debt-equity ration.	
		Million $
	Debt (12 year financing from GE Capital)	21
	Equity	4
	Total	25
Power purchaser:	Instituto Costarricense de Electricidad under a 15 year PPA	

3.4 Solar Thermal Electricity Developments

3.4.1 Summary of results from survey of institutions

The following general conclusions were drawn from the interviews carried out with institutional players in India during October 1996 Notes of the interviews are included in Annex 5.

- The interviews carried out with key players in India (governmental, financial, private developers and utilities) have confirmed the high level of interest in these technologies.
- There is currently no official Indian government policy with regard to the development of STP power However, the GOI are providing a grant to the Mathania parabolic trough development
- There has been a lot of interest in these technologies, especially in Rajasthan, where a Solar Energy Enterprise zone is being set up, aiming for 1000MW of installed solar capacity by 2005. Madhya Pradesh and Tamil Nadu states are also actively involved in developing STP projects
- In 1993, MNES put out a call for proposals for grid connected solar thermal power plants. 70 parties responded, but only 6 went on to submit a detailed project report to MNES.
- The Rajasthan Energy Development Agency recently issued a call for proposals for solar IPPs in Rajasthan This call set a tariff structure to be applied, and resulted in 3 letters of intent for BOOM projects One of these was for a STP project (200 MW_e solar chimney)
- The development of wind power in India was very much government led. MNES purchased and tested wind turbines, and carried out the necessary resource assessments. They then invited private parties to carry out commercial developments.
- Incentives for STP developments include 100% depreciation in first year; no sales tax, and no excise duties (these are discussed further in Section 2.4).
- Some parabolic dish systems have been demonstrated in India in the past. These demonstrations were not successful, as the availability of spare parts for the imported systems was limited.
- There is some uncertainty with respect to the reliability of stirling engines in a rural application;
- The main barriers to further STP developments are the costs and the low capacity factor;
- Opportunities exist in the industrial sector, which currently relies heavily on diesel captive power.
- SEBs should have no problem accepting STP power, although the format and procedure for setting up PPAs is still not finalised in India.
- IREDA are not currently involved in STP, as their focus is on commercialisation. IREDA are interested to be start financing STP projects, but the technology needs to be either proven in country, or proven overseas with accompanying R&D to demonstrate applicability in India.

- There are power developers within India who have been trying to develop STP technologies for several years now. Projects have not materialised mostly due to the failure to achieve funding for the projects. These developers appear confident that the market is there in India for STP plant and see the main barrier as the lack of financing available for both pilot plants and commercialisation.
- In the medium term, it was generally accepted that STP developments would be realised on an IPP basis. However, there was great concern that mistakes of the past would not be learned from, and insufficient in-country manufacture, spares and expertise would be provided.
- Past failures have highlighted the need for the current study, which has generally been welcomed by all parties as a positive step to rectify these operational problems. Many people are keen to receive further information on STP which will help them make informed decisions as to how best to implement projects.
- In the short term, the need for demonstration of STP technologies in India was recognised. Some parties were not convinced that an IPP route was ideal for a demonstration project.
- There are currently some funding programmes (e.g. those administered by ICICI) offering loans at preferential rates for pilot installations of innovative energy technologies.
- The REC are currently in the process of assessing different Renewable Energies with respect to their use in rural locations.

3.4.2 STP Experience In India

Some investigation of STP activities within India has been described in Section 1. The following two example projects (neither yet realised) highlight different possible project structures.

3.4.2.1 Luz Punjab

The following STP project in India was proposed in 1987, but was never realised:

Luz Punjab Proposal

Background:	Proposal for a development in Punjab State prepared in 1987.
Technical:	30 MW of parabolic trough with parallel boiler using coal and/or biomass.
Developer:	Project developer to be a new, private Punjab company. Equity from Punjab Agro Industries Corporation Ltd (PAIC, State Government undertaking) and Ballarpur Industries Ltd.
Financial:	

	Million $	**%**
Commercial loan	26	33
Soft loan from bilateral	26	33
GOI Grant	15	20
Equity	11	14

15 year average generation cost 7 US c/kWh (1986)

Technical work:	Engineering Company to be set up for technical work, and to establish manufacturing and O&M capabilities. Equity from Luz International Ltd, PAIC and Ballarpur.

3.4.2.2 *Mathania, Rajasthan*

The following summary of this project is based on the most up to date information available. It should be noted that the project is still under consideration and the structure is not finalised. Further details are included in the GEF Project Proposal report.

Mathania Project, Rajasthan	
Background and technical details:	See Section 1.2.1
Status:	As of November 1996, GEF and KfW funding are in place and the project is awaiting approval from the Department of Economic Affairs. Sticking points are exactly how the project is going to be structured, and who is going to implement the project. A final decision is expected in the early part of 1997, and an ICB is expected shortly afterwards
Development Structure:	An IPP route is planned. Current thinking is that the project will be implemented by the Rajasthan State Power Corporation Ltd (a recently established concern wholly owned by the state government)
Financial:	Approximate total cost US$280 million, financed by a mixture of a GEF grant, loans (from commercial organisations and bilateral soft loans), and equity as follows: GEF grant US$49 million (US$4 million for technical assistance) GOI grant US$10 million KfW soft loans Dm250 million GOR equity US$10 million IPP equity

The total investment cost of the Mathania project has been estimated to be $US 240million. Using a baseline case of a coal-fired 140MW power station, the marginal costs of the solar plant have been estimated to be US$83 million (about $2,400 per kW).

All going to plan, the Mathania project will be the first time that a STP plant will be commissioned through competitive bidding. The State Government of Rajasthan will issue a Request for Proposal (RFP) for a power plant to be located at Mathania with an aggregate capacity of about 140 MW having 35 to 40 MW solar plant component. Choice of secondary fuel for the power block will be left to the bidder.

Once installed, the plant will operate autonomously as an IPP and will sell power to the grid based on a PPA with RSEB. Ideally, the purchase price will be fixed in a manner to enable the IPP to repay its loan obligations as well as meet all its operating expenses.

3.4.3 Assumed STP market development in developing countries

The current market status of STP technologies is illustrated in Table 6 (Section 1). The lack of any completed, benchmark STP projects in Asia means that any assessment of the institutional issues must involve a certain degree of extrapolation from experiences in other sectors. An assessment of this kind therefore makes certain assumptions about the way the market for these technologies will develop in the future.

The following market development scenario has been assumed for the purposes of this assessment. This has been constructed on the basis of.

- IT Power's and TERI's knowledge and experience with this and other renewable energy technologies in India
- The survey of institutional players (Section 3.4.1)
- A review of recently published STP market predictions and support (Annex 6)
- Published information on the way that other renewable energy technologies have developed in India.

A particular example of this last point is the development of wind power generation in India, which was encouraged by a series of pilot installations. Once data had been gathered on the performance of different wind systems and products in country, a programme of commercialisation was set up, with support from the GEF. This programme encouraged private sector initiatives, and an industrial base for wind equipment supply and engineering is now emerging in India, with as many as 26 joint venture companies, some of which are poised to enter the export markets[xxvi]. Establishing wind in the commercial mainstream has involved concerted efforts on the part of government and the private sector to establish agreements amongst policy makers, power utilities, manufacturers, financial entities, investors, contractors and consultants.

The following scenario is assumed for the development of STP in India (Figure 9).

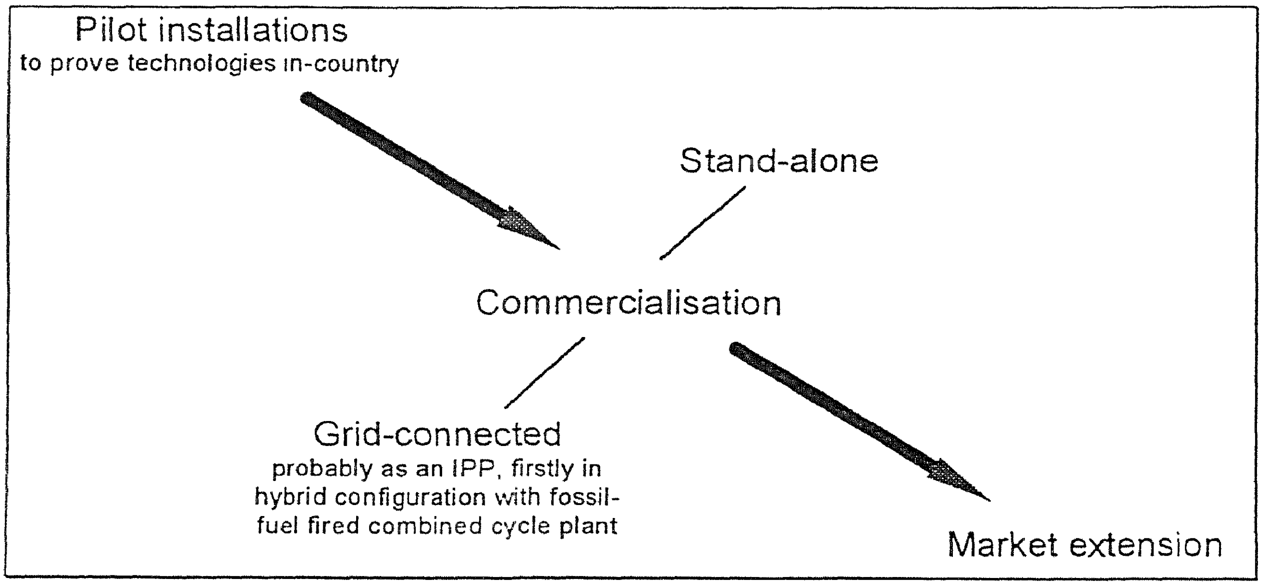

Pilot installations
to prove technologies in-country
Stand-alone
Commercialisation
Grid-connected
probably as an IPP, firstly in hybrid configuration with fossil-fuel fired combined cycle plant
Market extension

Figure 9: Market Development Scenario

Assumptions implicit in this market development scenario are as follows:

- Continued international technical R&D effort on STP technologies, and particular focus on reducing installed costs, reducing running costs, improving performance and new, innovative technologies.
- International commitment to pilot projects and market development programmes, especially in developing countries.
- Commitment from national government.

- Confidence in STP amongst financial institutions and availability of suitable financing for installations (both pilot and fully commercialised). Financing sources include:
    - Grants (from public sources)
    - Equity (e g. from developers or equipment suppliers)
    - Debt
- Appropriate structure of electricity industry e g suitably developed IPP and PPA arrangements.
- Contractual matters unique to STP developments are resolved. For example, there is an added meteorological risk This must be accounted for and allocated appropriately
- Availability of appropriate incentives, such as tax breaks.

The lack of realised STP projects in Asia is a barrier to attracting private investment and loans, as the perceived technical risks are high Therefore, a program of pilot projects is required, subsidised by grants from public bodies, to instil confidence amongst private investors and banks so that they are willing to take on the commercial risks.

A lesson learnt from the STP developments in California is the need for an incentive structure that would enable prospective investors to view the operation of the STP facility as an integral part of their corporate business rather than as a mere tax shield or marginal investment.[xxxi]

Once the technical risks are reduced, a commercialisation programme will be required to attract private industry to STP developments. Again, some public resources and incentives would be required for this programme, for instance, in the form of soft loans.

Although we have not suggested any timescales to this development scenario, it is worth noting that, under the EC's development strategy, STP is expected to be generating at around 5 US cents by the year 2015 The EC has estimated the market in India to be 800 MW_e per year (this is described in more detail in Annex 6).

3.4.4 The Role of Institutions in STP

On the basis of this STP market development scenario, it was possible to predict the role that different institutions will play (Table 35)

Table 35: Role of institutions in STP development

	ROLE
GOVERNMENT	
International	[illegible] STP technologies and technology transfer
National	Removal of any subsidies for fossil-fuel generated electricity Prioritise STP technologies for bilateral aid Establishment of suitable industry structure, pricing mechanisms, contractual structure and performance specifications Granting of all the necessary permits Other normal IPP activities e.g. counter guarantees Development of a programme for pilot installations and commercialisation of STP technologies
Local	Encouragement of renewable energies Local planning issues
Rural electrification	Development of a programme for pilot installations and commercialisation of STP technologies suitable for stand-alone operation Development of suitable arrangements for attracting private investors to rural electrification projects
FINANCIAL PARTIES	
GEF	Grants to encourage pilot installations (both grid connected and stand-alone), based on the incremental cost of the STP development
Multi-lateral agencies	Soft loans and equity during commercialisation stage
Bilateral agencies	Grants and soft loans during pilot and commercialisation phases
National and local governments	Grants, loans and equity during pilot and commercialisation phases
Financial Institution (e.g. IREDA)	Commercialisation of STP technologies
Equipment suppliers	Invest equity in IPP development
Banks	Loans
UTILITIES	Power Purchase Agreements Regulating quality of electricity exported to the grid
DEVELOPERS	BOOM contracts with utilities Equity for STP plant (probably in conjunction with a conventional fossil-fuel plant)
OTHER	
Turnkey contractors	Construction activities. May also hold equity in the project company
Research institutes	Development of STP technologies Monitoring performance

MNES have already put forward a two fold strategy for development of STP in India[xxxii]:

1. A 30 MW R&D / demonstration project (Mathania)
2. Promotion of 10MW BOO private sector projects, with partial financial assistance from MNES, at suitable locations in different states.

4. International Workshop on Solar Thermal Electricity Generation in Developing Countries, New Delhi, 1st March 1997

Full details of this workshop are included in Annex 7 All the goals of this workshop were realised. The following is a summary of these goals and some of the key findings of the workshop.

- Presented the preliminary findings of the ODA project
- Created awareness of the STP technology options and their current state of development amongst the audience of representatives from financial institutions, private financiers, development agencies, developers and Indian national and state government.
- Stimulated a lively debate between the participants and encouraged networking
- The following comments were made by various departments of the Indian Government:

  MNES
  - An STP R&D programme is planned for India, including a feasibility study for a central receiver plant
  - The Rajasthan solar zone has been set up with the goal of realising 1GW of installed solar by 2010
  - MNES can see advantages to starting on smaller pilot projects (kW rather than MW)

  IREDA
  - IREDA have not financed any STP projects and currently have no formal STP loan structure in place
  - IREDA are currently seeking to set up a STP technology development fund

- Identification of the barriers to STP development, and in particular the financial barriers

  - Lack of funding for small projects within India
  - The current prices of STP are uncertain to say the least, and estimates vary. There is no real "market" price, as there is currently no market. Projections of future prices are even more uncertain.
  - Perception (amongst traditional power developers) that the technology is too risky to consider

  Institutional barriers
  - Financially insecure utilities in India with no credit rating. and hence uncertainty surrounding any PPA.
  - Political barriers

- Development of a strategy to overcome these barriers

  - The on-going Mathania project is designed to help overcome some of the uncertainty surrounding these technologies
  - There was a call for loans, support for feasibility and pilot projects from private developers

5. Conclusions

Background

An important lesson that can be learnt historical STP projects in India is the importance of including training of operation and maintenance staff in any STP project, as well as ensuring that spares are provided or are readily available in the future.

Electricity Supply and Demand Factors

Utility owned power generating capacity in India has increased at a rate of over 10% per year since 1950 Despite this, there is today a chronic shortage of grid electricity, and a great deal of inefficiency in the electricity system This is illustrated by the following key statistics for Indian electricity supplies:

- A peak capacity deficit of 16%
- An electrical energy deficit of 7%
- Transmission and distribution losses of 22%
- Generation capacity load factor of 58%

As a result, in the short term, the Indian grid can absorb additional capacity without any particular problems associated with the low capacity factor of STP plants or the timing of STP generation.

There are important opportunities for using STP technologies in remote locations, such as the Andaman and Nicobar Islands in India. There are 572 islands in this group, and they are the most remote region of India. Only 38 of the islands are inhabited, and almost all the electricity is generated by 30MW of diesel generator capacity. The diesel has to be transported from mainland India. which adds almost 30% to the cost. In addition, the emissions from the generators are particularly harmful to the flora and fauna of the islands.

These are the types of issues which start to make STP plant a more appropriate generating technology for these remote areas. Parabolic dish systems are particularly appropriate for these applications, as they offer smaller capacities. In order to achieve an acceptable capacity factor, a hybrid system would be required, perhaps with a diesel generator back-up. In this context, the STP plant would be saving diesel fuel costs, and not diesel capacity. However, in these remote areas, even modest savings in diesel fuel may justify the investment.

Electricity Interface Requirements

STP technologies utilise many of the same control and synchronising techniques as fossil-fuelled power plant However, the output from the solar field is less controllable. During cloudy conditions, it is likely that the output from the solar plant would suffer rapid variations, leading to the alternator tripping in and out of grid connection. From a grid management point of view, it is far from ideal to have a generating station which can quite suddenly trip out of the grid with very little prior warning. It is for this reason that energy storage and/or fossil-fuel back is normally incorporated in a STP plant.

In-country manufacturing

Most of the conventional power components used in STP developments (turbines, boilers, alternators, cooling systems, pumps etc) are already manufactured in India and can be procured locally.

The more specialist STP components (such as high reflectivity low iron curved glass, specialist absorbers, heat transfer fluids, tracking systems etc) cannot currently be procured within India. Given appropriate technology transfer and investment, there is no reason why these specialist components could not be manufactured within India. However, the private sector will not make the necessary investments until there is a sustainable and sufficiently large market for these components. Until this time, some imported components will be required.

There are certain STP technologies which utilise fewer specialist components. These include systems which do not require curved reflectors[5], solar ponds and solar chimneys.

Operational Economics

The conclusions of the economic analysis were as follows:

- For certain decentralised applications, solar thermal power generated using parabolic dish technologies would be more economically viable than grid extension
- A capital subsidy of 30% would be required to make solar thermal power generation using parabolic dish technologies in a decentralized application competitive with that from a diesel generator
- In centralised, grid-connected mode, although presently the electricity from any of the solar thermal technologies is costlier than traditional fossil-fuel sources, parabolic trough-natural gas with 25% solar share appears to be the most economically attractive option

There were several limitations with the model and data used for this analysis. Firstly, the data on capital costs was a mixture of real project experience and projected costs. Also, the published data on costs referred to a variety of plant sizes. Despite these limitations, the overall trends indicated by the model and the resulting conclusions are considered to be valid.

Operations and Maintenance

The O&M requirements of STP plant can represent up to 20% of the life cycle. They can also represent an important source of employment for local personnel. A 80 MW_e parabolic trough plant has been estimated to require about 50 permanent qualified employees, mostly operators, a maintenance group and plant administration.

There is evidence to suggest that previous STP pilot projects in developing countries have not placed sufficient emphasis on the continued successful operation of the plant. Insufficient support, training and spares have been supplied to enable long term operation.

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[5] Messrs Solar Power Corporation of Ahmedabad have developed a dish system which utilises flat reflector facets. Messrs Pitti Renewable Energy Systems of Pune are developing a line concentrator system which utilises a Fresnel lens.

It is essential that O&M requirements are considered at all stages of the development of a STP project. This is particularly true for developments involving large proportions of imported technology, rather than components that have been manufactured locally. As a minimum, the development must include the following items:

- Adequate training of local operation and maintenance personnel;
- Design and implementation of an methodical operation and maintenance programme;
- Technical support for O&M personnel;
- Supply of sufficient spares, especially of particularly specialist components, which may have a long delivery time;
- Establishment and implementation of an appropriate warehousing programme for maintaining the stock of spares at the site.

In addition, it is important that there are commitments from the suppliers of components that spares will be available for a certain number of years (preferably at least 20)

It is also important to ensure that the project is financially viable throughout its whole operating phase, and to include adequate insurance and reserves in the financial planning. Otherwise, the situation might arise where it is no longer economic to maintain the plant, and it will fall into disuse

Site Selection

There are many factors which must be considered when assessing a site for a STP plant. Some of these are technical necessities (such as having stable ground conditions on which to develop the plant). Others are conditions which will ensure that the maximum output is achieved from the STP plant. Generally, they can be spilt into three categories:

- Meteorological conditions
- Local conditions (such as soil stability)
- Infrastructure conditions (such as proximity to water supplies and the electricity transmission network)

Land Use

An assessment of the land use requirements of the various STP technologies was carried out. The following is the resultant ranking of land use. from least to greatest:

- ◊ Dish-Stirling
- ◊ Parabolic Trough
- ◊ Central receiver
- ◊ Solar Chimney
- ◊ Solar pond

The impact of this land use will vary from site to site. Possible impacts include:

- Social (e g population displacement)
- Environmental (e.g. visual appearance, destruction of areas of importance for nature conservation)
- Economic (e g. use of land that has other economic uses such as agriculture).

Environmental Impacts

In common with all solar and renewable energies, the main environmental benefits of STP are associated with the reduction in fossil-fuel combustion and associated emissions of:

- Greenhouse gases (mainly carbon dioxide)
- Acidic gases (oxides of nitrogen and sulphur)
- Particulate material

In India, the construction of a STP plant is likely to replace the construction of a coal-fired power station. Coal power stations have the largest emissions of greenhouse gases per unit of electricity generated. Avoiding coal-fired generation is therefore particularly environmentally beneficial. In terms of the greenhouse gas carbon dioxide, the cost of avoiding emissions using a parabolic trough collector could be as low as $50 per ton CO_2.

Given the number of old, inefficient coal-fired power stations being operated in India, the incorporation of STP into a refurbishment programme for these stations would be particularly appropriate The STP plant could operate in parallel with the refurbished coal boilers, which would provide the back-up. A project of this nature is currently under development in Spain.

One of the most environmentally hazardous material used in STP technologies is the synthetic heat transfer oil for parabolic trough developments. At operational plants in California, several thousand litres of oil are emitted each year, mostly as a result of gross failure of pipework or fittings. Generally, the oil contaminates a small area of soil, which is removed for decontamination.

It is clear that tight controls and continued monitoring of STP plants is required so that failures of this kind are noticed and repaired quickly Appropriate procedures for spillage control and site remediation should be in place and reviewed regularly.

Safety Issues

Particular hazards associated with STP technologies include:

- Falling glass
- Burns from handling of unguarded hot components
- Overheating of the absorber due to pump failure
- Ruptured pipework emitting heat transfer oils at high temperature
- Faulty control systems leading to a shift of the focus point of a field of heliostats away from the absorber.
- The use of sodium filled heat pipes in certain parabolic dish-stirling engine systems
- Structural safety of a very tall solar chimney

Most of the risks associated with STP plant can be minimised by:

- ◊ Careful attention to the design of the system and site
- ◊ Incorporation of fail-safe control mechanisms
- ◊ Implementation of a methodical maintenance and monitoring programme

Decommissioning Factors

Although decommissioning of power plant is not normally considered in India, it is prudent to include some consideration of the decommissioning issues during project development. Many of the issues are common to all power developments, such as the dismantling and removal of large quantities of steel and concrete. Others are unique to STP developments, such as the removal of the large quantities of glass and possibly heat transfer oils at the site.

Institutional Assessment

A Market Development Scenario was developed to try to predict how STP is likely to develop in India, and in developing countries in general. On the basis of this scenario and the other information collected, it was possible to identify the likely role of the key institutional players in this future market.

Other key conclusions from this assessment include:

- There is currently no official Indian government policy with regard to the development of STP, although there have been activities in this field (most notably, the planned 35 MW_e plant planned at Mathania)
- Renewable energy incentives which would apply to STP projects include 100% depreciation in first year; no sales tax, and no excise duties
- The main barriers to STP developments are the costs, the low capacity factor and the lack of finance for pilot projects
- In the medium term, it was generally accepted that STP projects would be realised on a IPP basis, although there was some uncertainly that this is the best way to handle pilot projects
- There was some concern that the mistakes of past projects would be repeated, and that there would be insufficient in-country manufacture, spares and training.

International Workshop on Solar Thermal Electricity Generation in Developing Countries, New Delhi, 1st March 1997

All the goals of this workshop were realised, namely:

- Presented the preliminary findings of the ODA project
- Created awareness of the STP technology options and their current state of development amongst the audience of representatives from financial institutions, private financiers, development agencies, developers and Indian national and state government.
- Stimulated a lively debate between the participants and encouraged networking.
- Clarification of the position of the Indian
- Identification of the barriers to STP development, and in particular the financial and *institutional barriers*
- Development of a strategy to overcome these barriers

6. Recommendations

The environmental analysis in Section 2.8 has indicated that there is real potential for incorporating STP technologies into the refurbishment of old, inefficient coal-fired power stations in India This type of project would have great environmental benefits, both due to the upgrading of the coal boiler, and due to the displacement of coal by the solar field.

What is required at this stage is a pre-feasibility study to assess the technical options available and to try to identify suitable power plants This study would have to take into account the following:

- An installation of this kind is currently planned in Spain;
- KfW have had some talks with NTPC in India on this subject;
- The existing nature and timing of the maintenance / refurbishment programme for cola-fired power stations in India.

The results of the economic analysis in Section 2 4 indicate that parabolic dish technologies would be cost-effective compared to grid-extension in certain rural situations. Further research work is required to define the optimum configuration of plant (in terms of back-up energy sources and possibly storage options).

There is a running theme throughout several of the sections that highlights the need for quality projects, not purely in terms of hardware, but in terms of establishing the training and maintenance programme that will ensure the long term viability of the plant. This is particularly important in developing country projects, where some specialist component and skills will be imported and therefore will not automatically be available in-country. There is a need for a clear definition as to exactly what quality criteria are important, and what minimum standards need to be met.

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ANNEX 1: Background on Solar Thermal Power (STP)

A1.1 Description of STP technologies

For generation of electricity through solar thermal energy, several technologies are now either available or strongly feasible. They are listed below·

1. Parabolic trough system
2. Central receiver system
3. Parabolic dish system
4. Solar chimney power station
5. Solar Pond power station

They are described in detail in the following text. Figure A1.1 is a summary of the different variants that are currently available or under development Table A1.1 gives details of the performance of the most efficient example of each type of technology.

Solar Chimney Power Station

In a solar chimney, the greenhouse effect is realized by simple air collector, which is a large surface area covered with either glass or transparent plastic sheet. The incident solar radiation passes through this covering and strikes the ground. Here it is converted into heat, which in turn heats up the air. The air thus heated flows radially through the collector towards the base of the chimney and rises through the chimney. In the process this air operates the vertical axis wind turbine, installed inside the chimney. This way the electrical power is generated through the alternator, coupled with the wind turbine. But this kind of the system has low overall efficiency and as such relatively larger land area is required. Also, plant load factor is low due to less power output during non-sunshine hours.

Solar Pond Power Station

Solar pond is the only direct solar thermal system having an integrated energy collector and storage at a large scale. In a normal, fresh water reservoir, once the water gets hot by absorbing the solar radiation, convection currents would set up. Thus the heated water rises to the surface and loose heat to the atmosphere. But in a salinity gradient solar pond. thermal convection is suppressed because of unfavourable salinity gradient. The large mass of saline water in the lower most zone thus gets transformed into a large thermal storage from which heat could be extracted for driving the organic Rankine turbine. While the overall efficiency of such a system is of the order of 5% only. the advantage is that is operates on both, direct and the diffuse portion of the insolation. Also, by virtue of having an in-built thermal storage, it can be operated at any time any season. But considering the present costs of power generation system for solar ponds, it is desirable to operate the same at a high capacity utilization and not in the peaking mode.

Parabolic dish system

The system consists of parabolic dish which concentrates solar insolation onto a receiver at its focal point. The energy is absorbed and converted into thermal energy, in the receiver. This thermal energy can be either transported to a central generator or it can be converted directly into electricity at an engine/generator mounted on the focal point. In the latter mode, the engine too is tracked along with the dish. The tracking is done along two axes. In another arrangement, high pressure vapour is generated in the receiver and the vapour then drives a turbine. After condensation, the fluid is again passed through the receiver.

The gas-turbine generator could use either Brayton or organic Rankine cycle. This technology is yet to be adapted to large scale applications but it could be a cost-effective way of generating electricity for decentralised or stand-alone applications. Due to the fact that parabolic dish system is modular, responds quickly to changes in solar radiation, is easy to operate, and capable of high temperatures, it is well suited for use in distributed energy systems, at sites with an annual direct insolation of even less than 1800 kWh/m^2. A significant feature of this system is the high solar to electric conversion efficiency of around 28%. Also, because of very high part load efficiency, the mean daily efficiency is around 95% of the maximum. [3]

Parabolic trough system

The reflective surface of a parabolic trough concentrates sunlight onto a receiver tube, located along the trough's focal line. Heated fluid flowing in the tube can be transported through pipes to a heat exchanger, to generate the steam. This steam then runs the conventional turbine- coupled alternator. The parabolic trough tracks the sun along one axis. Here, the temperatures attained are lower than those in central receiver or dish systems. Also, energy storage is not as economically feasible for parabolic trough systems as it if for central receiver plant. The reasons being, (I) the smaller temperature difference between storage inlet and outlet temperatures, resulting in much longer and expensive storage vessels, and (ii) relatively higher cost of oil. Since the trough system generates less superheated steam in solar-alone mode, for example at maximum temperature and pressure of 370°C and 100 bar respectively, electric power generating system efficiency is lower at around 36 - 38% [4]. These systems are economical for peak power production under the favourable conditions and need plant capacity approaching 100 MW$_e$ to be economical.

Central receiver system

This system uses heliostats that track the sun and reflect it as well as concentrate it up to 1000 times to a central receiver atop a tower. This energy heats up a heat transfer medium to a maximum temperature range of 500 - 1000°C. The heated heat transfer fluid then drives a turbine to produce the electricity. These plants are suitable for power sizes up to 200 MW for solar - only operation and can be equipped with a thermal energy storage using for example, molten salt.

Table A1.1: Top performers of each variant of STP Technology

Technology	Name of plant	Location	Size (MWe)	Date of start-up	Solar-electric efficiency	Power conversion
Parabolic Trough	SEGS-VIII	Harper Lake, California	80	1989	14%	Rankine
Central Receiver	Themis	Targasonne, France	2.5	1982	-	Rankine
Paraboloc Dish	Vanguard I	Rancho Mirage, California	0.025	1984	23%	Stirling
Parabolic Dish	McDonnell Douglas/Unitied Stirling	Huntington Beach, California	0.025	1984	29%	Stirling
Solar Chimney	Manzanares	Spain	0.05	1982	0.05%	Wind Turbine

A1.2 Configuration Options

Like most renewable energy sources, solar thermal power generation is intermittent. In order to increase the Capacity Factor of STP plant, one can either use storage techniques or some form of back-up energy source. The different options which have been developed are described below.

A1.3 Storage Options

The use of thermal stores can increase the availability of the STP plant by a few hours into the evening. This can be particularly attractive if there is a need for peaking power in the evenings. Storage can also be used to improve the operation of a STP plant by buffering any rapid changes in solar output during the day (for instance when clouds pass overhead).

Oil heat stores were incorporated into the early Californian trough developments. the Solar 2 central receiver development incorporates storage of the heat transfer fluid itself (molten nitrate salts). Development has been carried out on latent heat stores in Germany, aimed mainly at parabolic trough systems. For systems operating between 250°C and 450°C, potassium and sodium salts are the preferred phase change materials.

Solar ponds naturally incorporate some thermal storage, due to the thermal capacity of the water itself.

A1.4 Hybrid Options

Where a fossil-fuel source is readily available, it is generally more cost effective to incorporate some sort of back-up firing rather than a thermal store. In developing countries, particularly in India, the cost-effective back-up fuels are coal, natural gas, and to a lesser extent naptha. In some cases, higher cost liquid fuels could be used. The following are examples of the different hybrid configuration options which have been developed.

The SEGS parabolic trough systems installed in California supply superheated, high pressure steam to a conventional Rankine cycle steam turbine. A gas boiler was installed in parallel to the solar circuit as a back-up. Under the contractual agreements for the plant, the gas contribution was limited to about 25% of the energy produced.

Some development has been carried out on similar configuration with the solar steam being used to compliment a fossil-fuel fired (e.g. coal) steam turbine plant. High pressure solar steam would be fed into the coal boiler for superheating (and reheating). Alternatively, lower pressure solar steam could be fed into the low pressure casing of the steam turbine.

Another option that has been developed for parabolic troughs is in combination with gas-fired combined cycle plant. This option has been referred to as an integrated solar combined cycle system (ISCCS). Integration of the solar energy is on the bottoming Rankine cycle, either at high pressure into the heat recovery steam generator, or at lower pressure directly into the low pressure region of the steam turbine.

There are thermodynamic limits to the energy fraction produced by the solar field in the ISCCS configuration (typically less than 10% of the annual energy output). One problem with this configuration is the necessity to oversize the steam turbine to accommodate the solar energy input. As a result, at times of no solar input, the steam turbine is undersized *and not operating at optimum efficiency. This can be avoided with careful sizing of the* plant and secondary fossil-fuel combustion in the heat recovery steam generator.

Some development work has concentrated on the options for inputting the solar energy into the topping cycle of a combined cycle plant. This could be by preheating the incoming combustion air, but the maximum solar contribution is low. Alternatively, high temperature and pressure air from the solar field could be fed directly to the gas turbine. Development of this configuration has included a ceramic absorber and high pressure window.

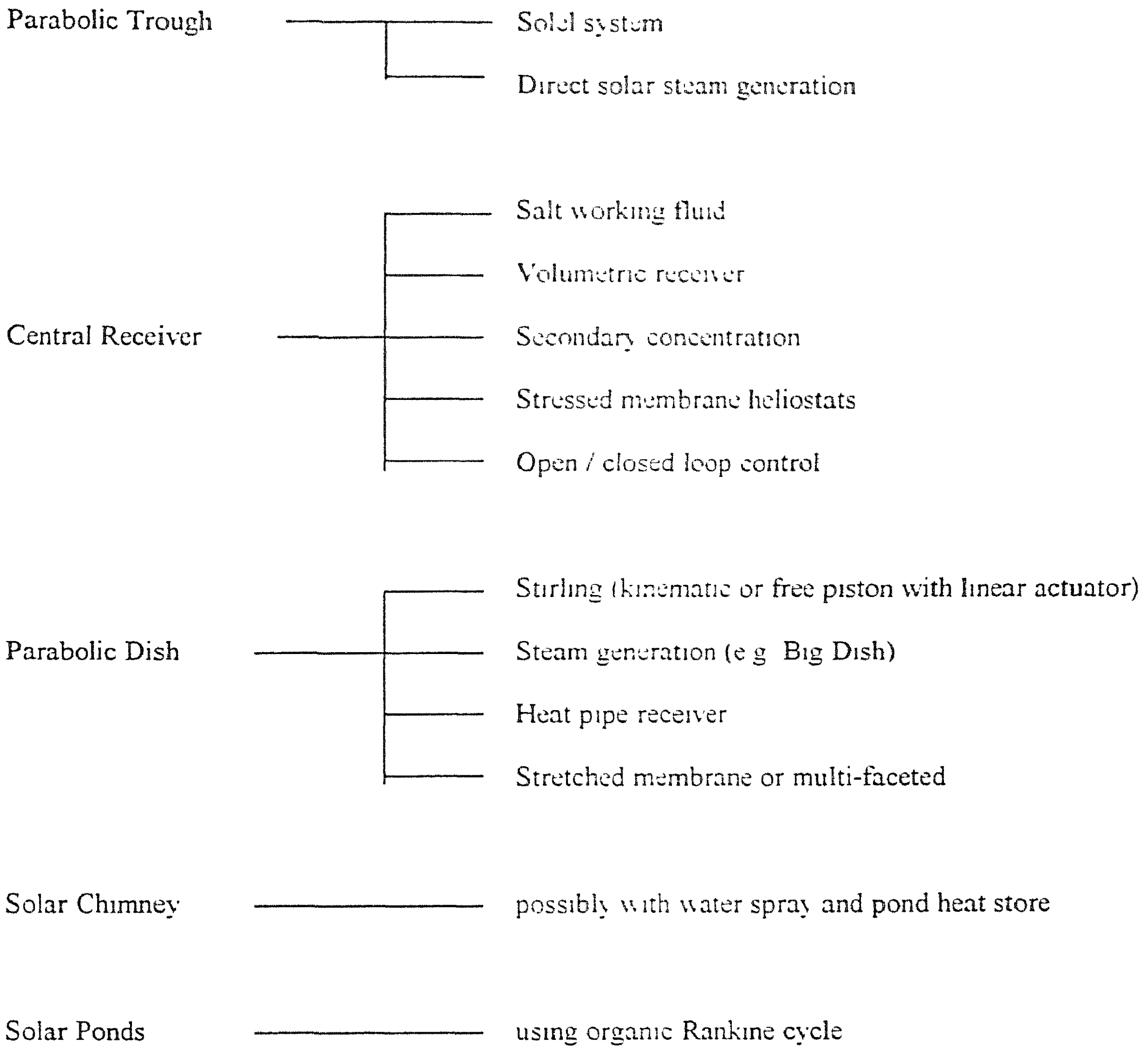
Other configuration options include:

- Secondary fuels used to heat stirling engines (only really applicable for parabolic dish systems)
- Chemical hybrids, where the solar source is used to increase the calorific value of a fuel (e.g. gasification of coal) which is then fed to a conventional power plant.

A1.5 Off-grid systems

It is possible to envisage a STP system operating off-grid in a stand-alone capacity. A mini-grid would be required, as well as a back-up energy source. Parabolic dishes are particularly suitable for this application, as they are available in relatively small modular units. A possible configuration would be a diesel generator / dish hybrid system, possibly with a battery bank to reduce the cycling of the generator.

In rural areas or islands out of the reach of the current electricity grid, stand-alone systems are often an economic alternative to grid extension. If the power demands are relatively low and dispersed, then photovoltaics are particularly suitable. For slightly higher, more concentrated loads, a STP hybrid system could be considered.



- Parabolic Trough
  - Solel system
  - Direct solar steam generation
- Central Receiver
  - Salt working fluid
  - Volumetric receiver
  - Secondary concentration
  - Stressed membrane heliostats
  - Open / closed loop control
- Parabolic Dish
  - Stirling (kinematic or free piston with linear actuator)
  - Steam generation (e g Big Dish)
  - Heat pipe receiver
  - Stretched membrane or multi-faceted
- Solar Chimney
  - possibly with water spray and pond heat store
- Solar Ponds
  - using organic Rankine cycle

Figure A1.1: Summary of technical variants categorised by concentrator system

Annex 2: Monitored data from a solar steam generation system at KSIC, Mysore.

7 pages to follow

[illegible] DATA FROM SOLAR STEAM GENERATION SYSTEM INSTALLED AT KSIC, MYSORE.

Hour	Amb. Temp. °C	Solar (dw) MJ	Inc. Angle deg.	Solar (in) MJ	Water				Collector field efficiency %	Steam		Remarks
					Flow kg/s	Tin °C	Tout °C	Energy Coll. MJ		Gauge pressure	Temp. °C	
8.30	26.0	251	27.75	213.2	1.463	44.0	52.0	88.2	39.7			The system was switched on at 8.00 A.M.
9.00	26.2	261	29.0	228.0	1.448	62.4	71.4	103.6	45.4			
9.30	26.5	282	30.24	244.0	1.342	87.0	99.0	122.0	50.0			
10.00	27.0	289	31.21	247.0	1.116	98.2	113.9	132.8	54.0	0.6	105.2	Steam was supplied to the printing section from 12.00 hrs. At 13.00 hrs, th line voltage was low and the pump could not produc sufficient pressure and hence the system was stopped.
10.30	27.5	303	32.0	257.0	1.065	109.8	128.5	157.6	58.9	0.8	115.1	
11.00	28.2	314	32.57	265.0	0.98	133.5	154.5	161.2	60.8	2.7	133.5	
11.30	28.3	314	32.92	264.0	1.00	138.8	159.5	159.8	60.5	3.5	142.3	
12.00	28.5	318	33.85	264.0	0.925	136.5	158.9	160.6	60.8	3.7	149.1	
12.30	28.5	310	32.85	260.0	0.911	138.0	159.8	153.9	59.2			
13.00	28.4	303	32.5	256.0	0.981	121.6	161.2	149.0	58.2			

Column : 1 is the hour in IST

Column : 2 is the ambient temperature in degrees Celsius

Column : 3 is the director normal solar radiation multiplied by the collector aperture area during the hour period.

Column : 4 is the solar radiation incident on the collector aperture during the hour, while collector tracking.

Column : 5 is the hourly average solar incidence angle in degrees.

Column : 6 is the average collector fluid flow rate in kg/sec.

Column : 7 is the average temperature of the collector fluid entering the collector field in degrees Celsius.

Column : 8 is the average temperature of the collector fluid leaving the collector field in degrees Celsius.

Column : 9 is the energy collected by the collector field during the hour period in MJoules.

Column : 10 is the hourly collector field efficiency, column [9] divided by column [5].

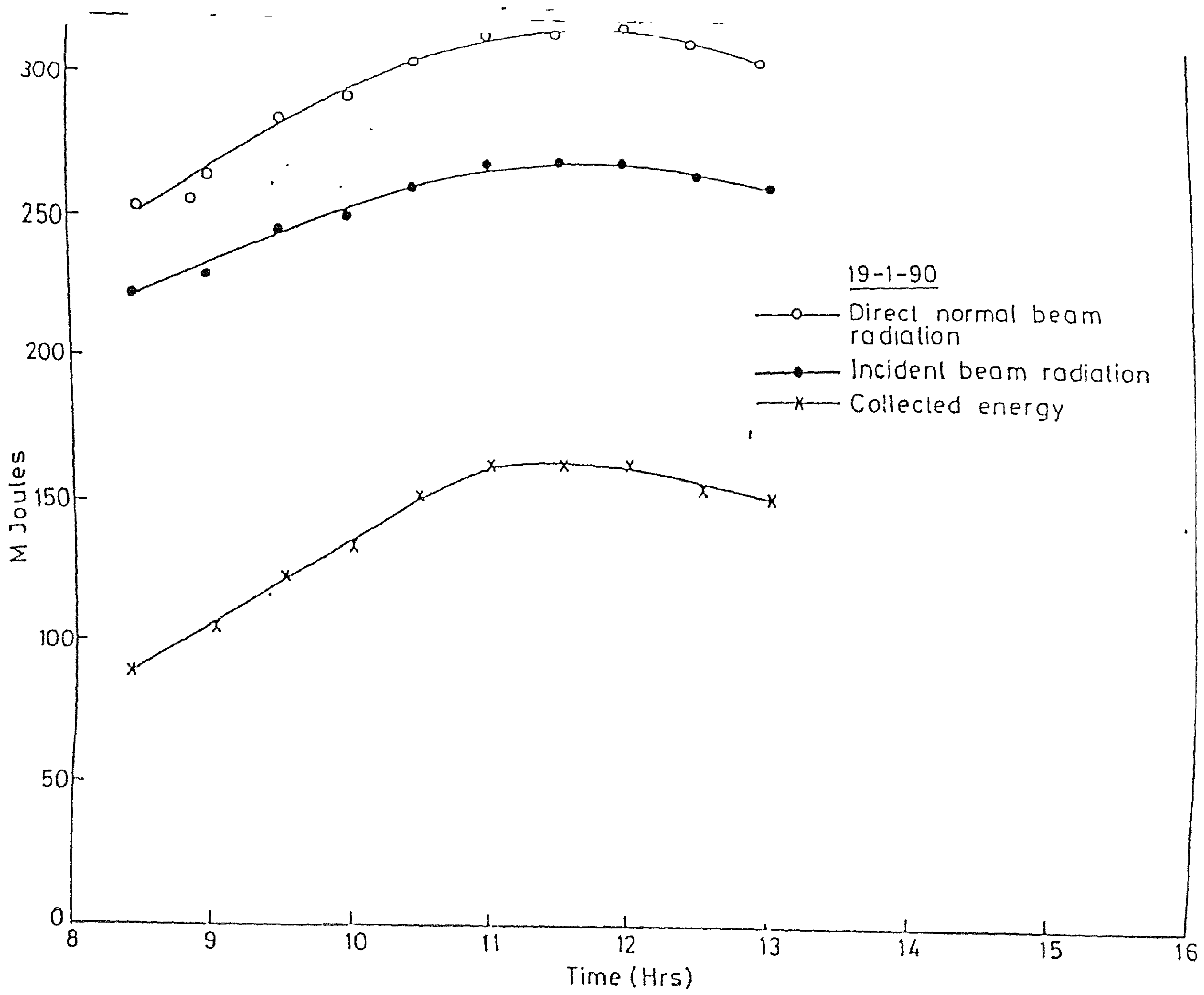


FIG. ENERGY COLLECTION SOLAR STEAM GENERATING SYSTEM, KSIC-Mysore.

Date: 20 Jan. 1990 DATA ON SOLAR STEAM GENERATION SYSTEM STALLED AT KSIC, MYSORE.

Hour	Amb. Temp. °C	Solar (dw) MJ	Inc. Angle deg.	Solar (in) MJ	Water Flow kg/s	Water Tin °C	Water Tout °C	Water Energy Coll. MJ	Collector field efficiency %	Steam Gauge pressure	Steam Temp. °C	Remarks
9.00	25.2	209.2	29.0	183	1.367	62.0	67.6	57.0	31.5	-	-	The system was switched at 8.00 hrs. Around 9.45 hrs there was a fault in the distribution switch of the 2nd row of collector and hence it was kept out of focus. At 12.00 hrs. it was rectified and recommissioned
9.30	25.5	256.0	30.24	219	1.33	84.7	74.6	100.5	45.8	-	-	
10.00	25.9	281.0	31.21	240	1.30	91.1	99.8	98.5	41.0			
10.30	26.4	286.0	32.0	243	1.31	106.3	115.7	93.5	38.5	0.2	106.3	
11.00	27.0	303.0	32.6	255	1.26	115.7	120.5	48.0	18.8	0.8	115.7	
11.30	27.5	303.0	32.9	254	1.22	129.1	137.7	90.7	35.7	1.6	129.1	
12.00	27.9	307.0	33.9	255	1.20	133.9	145.7	80.8	31.7	2.0	133.9	
12.30	28.0	307.0	32.9	258	1.21	141.1	154.8	117.2	45.4	2.75	140.5	
13.00	28.0	303.0	32.1	257	1.215	145.8	162.5	128.5	50.0	3.4	145.8	Steam to the pritning section was supplied from 14.00 hrs till end of their requirements (16.00 hrs.)
13.30	27.9	296.0	32.0	251	1.19	151.5	167.5	149.0	59.4	4.0	151.5	
14.00	27.6	286.0	31.1	245	1.11	150.0	167.7	165.5	60.5	4.7	156.0	
14.30	27.4	271.0	30.2	234	1.17	132.2	148.6	111.5	61.5			
15.00	27.0	267.0	29.1	233	1.09	127.0	144.0	146.6	61.1			
15.30	26.6	257.0	27.8	227	1.04	120.0	136.7	155.6	0.59			

Column : 1 is the hour in IST

Column : 2 is the ambient temperature in degrees Celsi

Column : 3 is the director normal solar radiation multiplied by the collector aperture area during the hour period.

Column : 4 is the solar radiation incident on the coll ctor aperture during the hour, while collector tracking.

Column : 5 is the hourly average solar incidence angle in degrees.

Column : 6 is the average collector fluid flow rate in kg/sec.

Column : 7 is the average temperature of the collector fluid entering the collector field in degrees Celsius.

Column : 8 is the average temperature of the collector fluid leaving the collector field in degree Celsius.

Column : 9 is the energy, collected by the collector field during the hour period in MJoules.

Column :10 is the hourly collector field efficiency, column [9] divided by column [5].

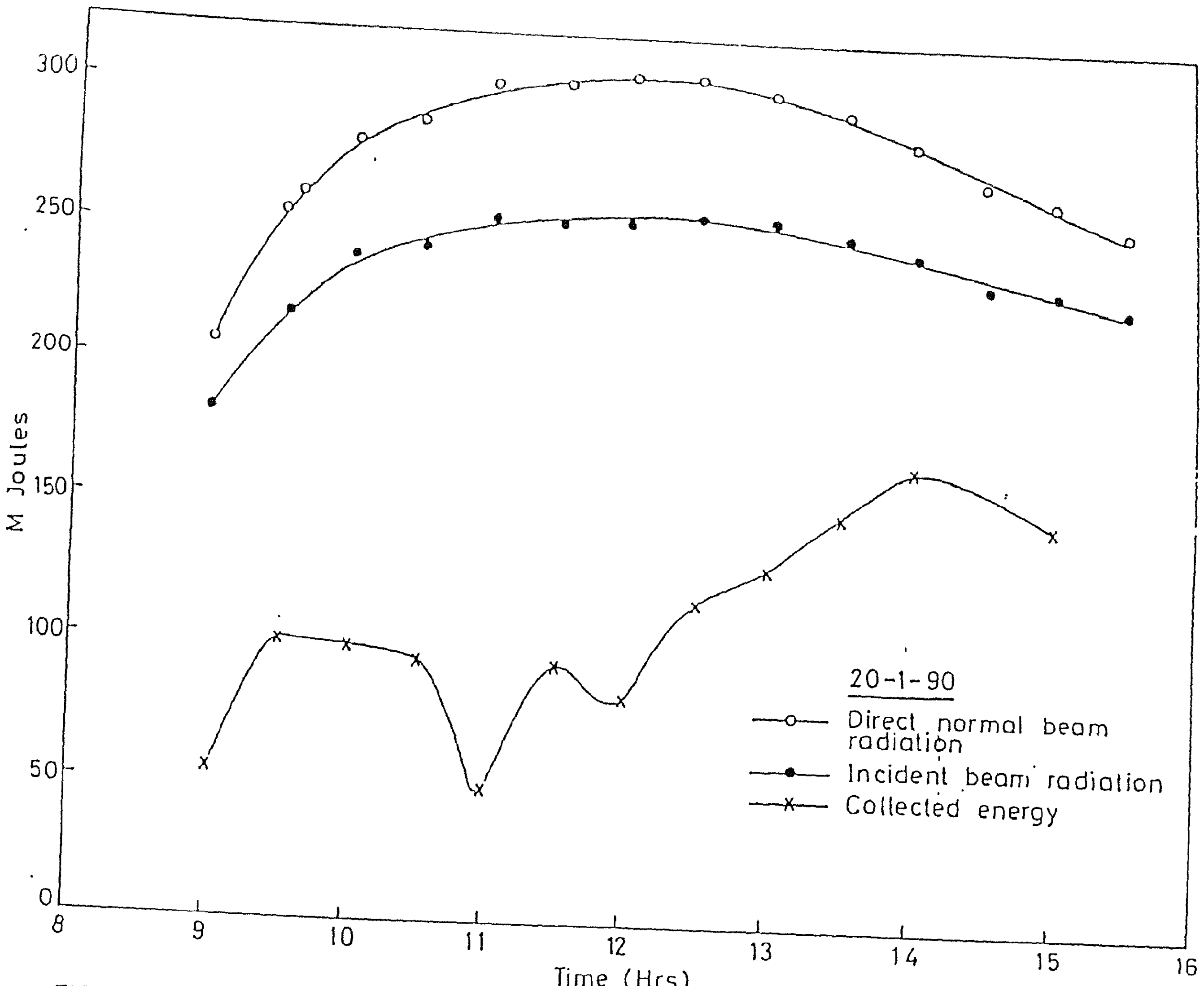


FIG. ENERGY COLLECTION SOLAR STEAM GENERATING SYSTEM, KSIC - Mysore.

ATE: 24th Jan.1990 DATA FROM SOLAR STEAM GENERATION SYSTEM INSTALLED AT KSIC, MYSORE

our	Amb. Temp. °C	Solar (dw) MJ	Inc. Angle deg.	Solar (in) MJ	Water				Collector field efficiency	Steam		Remarks
					Flow kg/s	Tin °C	Tout °C	Energy Coil. MJ		Gauge pressure kgs/cm^2	Temp. °C	
1	2	3	4	5	6	7	8	9	10	11	12	13
.30	26.0	69.7	26.75	62.2	1.24	53.2	57.8	26.1	42	-	-	The system was switched on at 8.15
.00	26.1	142.9	27.99	126.2	1.215	68.0	75.0	63.1	50.1	-	-	
.30	26.2	233.5	29.14	203.9	1.17	97.7	110.4	113	55.4	0.2	102	There was a total power failure between 10.05 to 10.25 hrs. Steam was supplied to the printing section at 11.45 hrs. Steam supplied was stopped because of low steam pressure
0.00	26.6	268.4	30.11	232.1	1.15	114	129.3	132.1	57.8	1.1	115	
0.30	26.8	273.6	30.9	234.8	1.12	117.5	130	106.7	45.4	1.2	118	
1.00	27.2	294.5	31.48	251.1	1.10	135.0	150.6	133.4	53.1	2.5	136.5	
1.30	27.6	298.0	31.88	253	1.07	143.3	165	164.0	64.8	4.5	154.0	Steam supply was resumed at 12.40 hrs till the end of process (15.45 hrs.) The system was shut down at 16.30 hrs.
2.00	27.8	298.0	31.94	252.9	0.99	153.4	174.5	165.2	65.3	5.0	155.0	
2.30	28.1	294.5	31.88	250.0	1.08	143.6	162.9	161.5	64.6	3.0	142.5	
3.00	28.1	291.1	31.48	248.3	1.07	139.2	158.2	157.6	63.5	2.4	139.0	
3.30	28.5	284.1	30.9	243.8	1.04	144	163	153	62.7	3.4	145.4	
14.00	28.7	277.1	30.4	239.0	1.05	154	172	149	62.3	4.5	154	
14.30	28.7	273.6	29.14	238.8	1.002	162.8	181.8	150.5	62.5	6.0	163.1	
15.00	29.0	268.4	27.93	237.1	1.006	161	179.2	145.2	61.6	3.2	160	
15.30	29.1	261.4	26.75	233.4	1.03	138	155	135.7	58.1	1.12	121	
16.00	29.0	252.7	25.31	228.4	1.04	142.4	158.9	133.0	58.2	3.1	143.1	

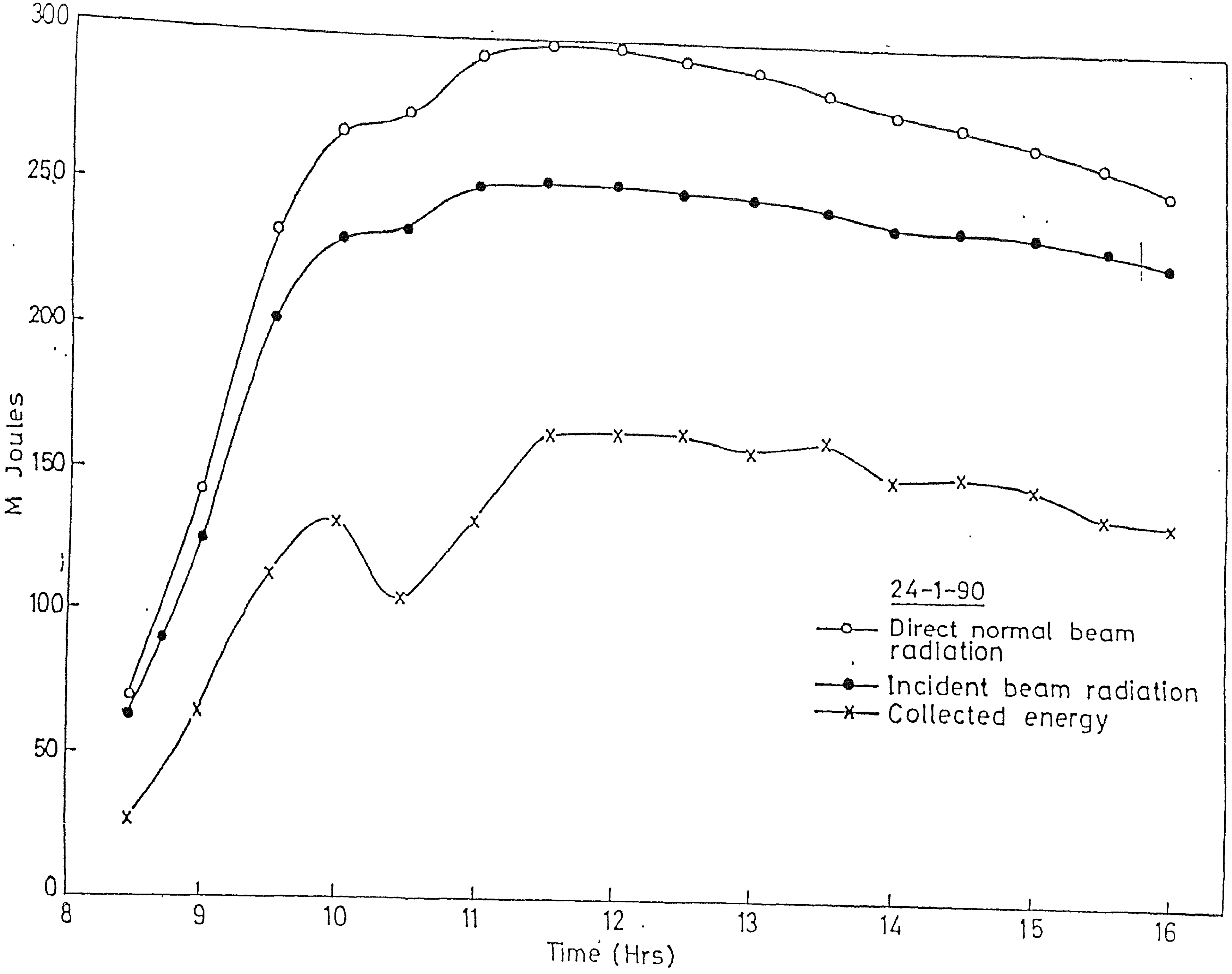


FIG. ENERGY COLLECTED-SOLAR STEAM GENERATING SYSTEM, KSIC-Mysore

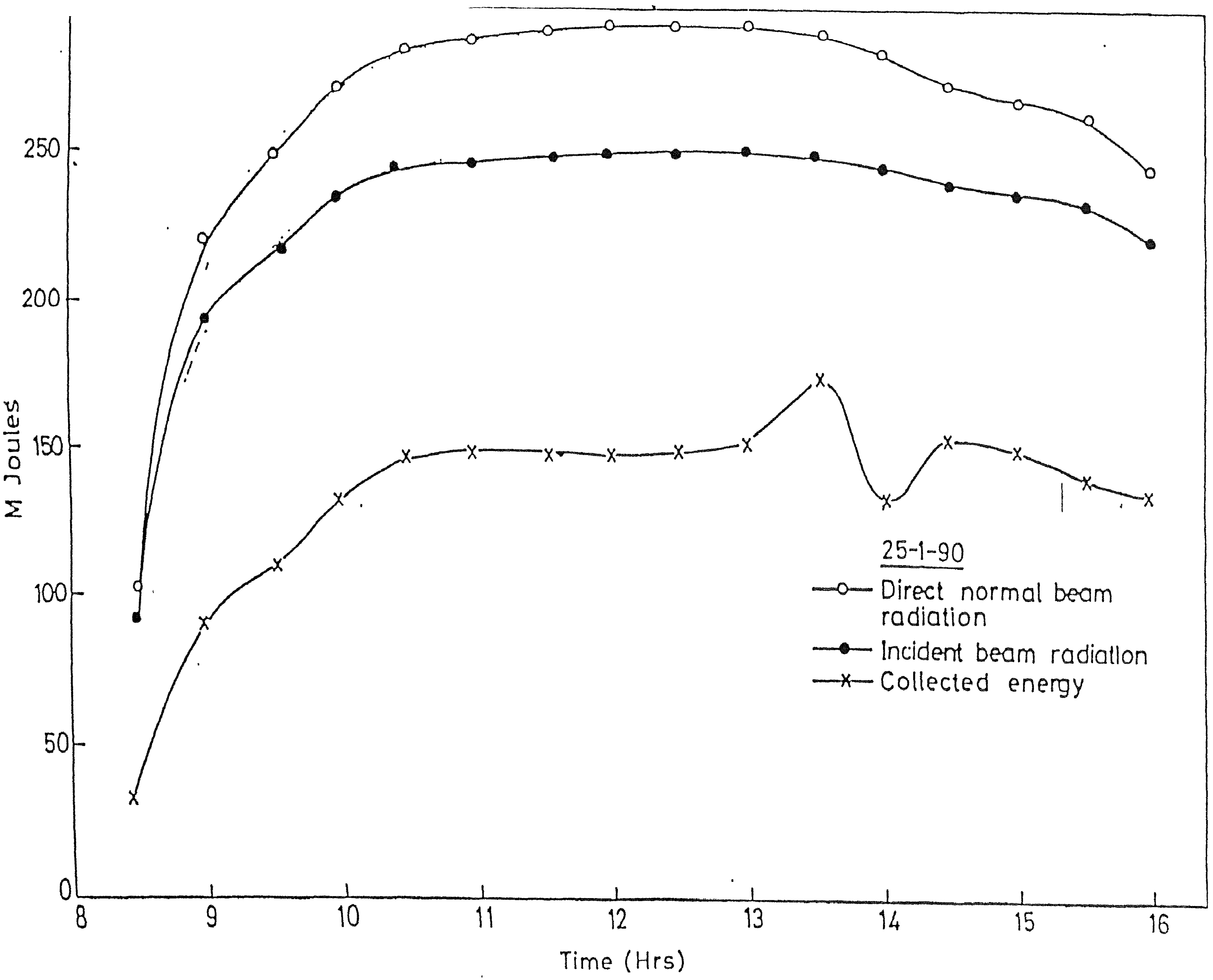


FIG. ENERGY COLLECTED - SOLAR STEAM GENERATING SYSTEM, KSIC - Mysore

Annex 3: Indian Companies which could potentially be involved in STP developments

1. Concentrators

(I) Radio Astronomy Centre
P B No. 8
Udhagamanadalam - 643 001
Tamil Nadu

2. Generators/Alternators

(I) Asea Brown Boveri Ltd.
Guru Nanak Foundation Building, 15/16
Qutab Institutional Area,
New Delhi

(ii) Bharat Heavy Electricals Ltd.
BHEL House, Siri Fort Road
New Delhi

(iii) Greaves Ltd.
Dr V B Gandhi Marg, Fort
Bombay

(iv) Kirloskar Electric Co. Ltd.
302 B, Poonam Chambers
Shivsagar Estate
Dr A B Road
Worli, Bombay

(v) Jyoti Ltd.
P O Chemical Industries
Vadodara

(vi) Siemens Ltd.
Power Generation & Distribution Division
4, A M Gandhi Marg
I P Estate, New Delhi

(vii) Bhaghem India
Dubash Building, 38
Walchand Hirachand Marg, Fort
Bombay

3. Transmission & Distribution Equipments

(I) ABB Ltd.
15/16 Guru Nanak Foundation Building
Qutab Institutional Area
New Delhi

(ii) Bharat Heavy Electrical Ltd.
BHEL House, Siri Fort Road
New Delhi

(iii) WS Industries (India) Ltd.
2nd floor, Unit No. 202
Creative Industrial Centre
M M Joshi Marg
Bombay

4. Electrical Controls & Switchgears

(I) Bharatia Cutler Hammer Ltd.
1101 New Delhi House
Barakhamba Road
New Delhi

(ii) Electric Control Gear (India) Ltd.
C/o Piramal Sons Ltd, Army Navy Building
M G Road
Bombay

(iii) Kirloskar System Ltd.
Atur House
Worli Nagar
Worli
Bombay

(iv) Larsen & Toubro Ltd.
P B No. 278, L & T House
Ballard Estate
Bombay

(v) Transformers & Electricals Kerala Ltd.
Flat No. 301, Rizvi Nagar
E - Wing
Santa Cruz (West)
Bombay

(vi) MDS Switchgears Ltd.
314/317 Shah Nahar Estate
Dr E Moses Road, Worli
Bombay

(viii) Havell's India Ltd.
1, Raj Narain Marg
Delhi

(viii) Controls & Switchgear Co. Ltd.
Central Marketing Office
44 Okhla Industrial Estate
New Delhi

(ix) Jyoti Ltd.
P O Chemical Industries
Vadodara

5. Electronic Controls & Timers

(I) Andrew Yule & co. Ltd.
32 Rani Jhansi Kamani Marg
Ballard Estate
Bombay

(ii) Hind Rectifiers Ltd.
Lake Road, Bhandup
Bombay

(iii) Onida Sanak Ltd.
A - 19 B - 1 Extension
Mohan Co-operative Industrial Estate
Badarpur
New Delhi

(iv) PBJ Industrial Electronics Pvt. Ltd
IEEC House
72 BCD Government Industrial Estate
Charkop
Kandivili (West)
Bombay

(v) S & S Power Switch Gear Ltd.
Empire House, A K Naik Marg, Fort
Bombay

(vi) Tata Honeywell Ltd.
72, Prepress House
Prepress Journal Marg
Nariman Point
Bombay

(vii) A G Engineering Enterprise
308 - A Mahim Industrial Estate
571 Mori Road, Mahim
Bombay

(viii) Puneet Industrial Controls (P) Ltd.
45 Community Centre
East of Kailash
New Delhi

6. Gear Boxes

(I) Bharat Gear Ltd.
Hoechest House Nariman Point
Bombay

(ii) Involute Tooling Corporation
Plot 65, Sector 27
Faridabad

(iii) Elecon Gears
Vithal Udyog Nagar, Anand

7. Condensers

(I) Air Flow Pvt. Ltd.
13/1090 Hardhian Singh Marg
Karol Bagh
New Delhi

(ii) Archana Plants & Equipments Pvt Ltd.
14th Floor, Control Main Building
M G Road, Fort
Bombay

(iii) Perfect Fin Tube Industries
44 Bomanji Lane Fort
Bombay

(iv) Reliance Heat Transfer Pvt. Ltd.
46 Veer Nariman Road, Fort
Bombay

(v) Reynolds Engineering Corporation
Mehta Estate, Near German
Remedies, Chakla, Andheri - Kurla
Road
Andheri (E)
Bombay

8. Reflector Material

(I) Annapurna Foils Ltd.
12/14 Oricon House, 4th Floor
K Dubash Marg, Fort
Bombay

(ii) Venlon Polyester Film (P) Ltd.
Plot no. 22 Phase II Road no. 9
MIDC Marol Industrial Area
Andheri (E)
Bombay

(iii) Enerjon Technics Co. Ltd.
`Chaitanya' Sheth C G Road
Ahmedabad

9. Radiation Sensors

(i) Central Electronics Ltd
Sahibabad

10. Pumps/valves/Tubes & Pipes etc.

(i) Hindustan Engineers
D - 127 Bonanza Industrial Estate
Ashok Chakravarty Road, Kandivili
(East)
Bombay

(ii) Indian Seamless Metal Tubes Ltd.
240, `H' Block, Indra Place
Connaught Place
New Delhi

(iii) Kirloskar Brothers
New India Centre
17 - A Cooperage Road
Bombay

(iv) Maharashtra Seamless Ltd.
Jugal Jyoti, 2nd Floor
176 CST Road, Kalina
Santacruz, Bombay

11. Cooling Towers

(i) Paharpur Cooling Towers Ltd.
Manek Mahal, 7th Floor
Veer Nariman Point, Church gate

Bombay

12. Bearings/Structurals/Thermic Fluid Boilers

(i) SKF Bearings (I) Ltd.
MGM Building, NS Road
Bombay

(ii) Southern Structurals Ltd
226 Kilpauk Garden Road
Kilpank
Madras

(iii) Thermax Ltd
Thermax House,
4 Bombay - Pune Road
Shivaji Nagar
Pune

13. Water Treatment Plants

(i) Ion Exchange (India) Ltd.
Tiecicon House, Dr. E. Moses Road
Mahalaxmi
Bombay

14. Glass & Glassware

(i) Atul Glass Industries Ltd.
3/9 Desh Bandhu Gupta Road
Paharganj, Delhi

(ii) FGP Ltd.
9, PB No. 1733, Wallace Street
Fort
Bombay

(iii) Float Glass India Ltd.
104/108
Keshav Bandra - Kurla Commercial
Complex
Bandra (E)
Bombay

(iv) Aashi India Safety Glass Ltd
12 Basant Lok, 2nd floor
New Delhi

15. Absorber tube coating

(i) National Aeronautical Laboratory
Material Science Division
Bangalore

Annex 4: Summary of GOI Policy for the Electricity Industry

oad features of the Private Power Policy of the Government of India are set out below:

The Indian Electricity Act, 1910 and the Electricity (Supply) Act, 1948 have been amended to bring about a new legal, administrative and financial environment for private enterprises in the Electricity sector.

Private Sector can set up thermal projects (coal/gas/naptha and other liquid fuel based), hydel projects and wind/solar energy projects of any size.

Electricity Projects where the total outlay does not exceed Rs.100 crore need not be submitted to the Central Electricity Authority for concurrence. The limit has been further raised to Rs.400 crore (being further raised to Rs. 1000 crore) in case of generation projects to be set up by generating companies selected through competitive bidding.

Private sector companies can set up enterprises to operate either as licensees or as generating companies.

All private companies entering the Electricity Sector hereafter will be allowed a debt-equity ratio up to 4:1.

Promoter's contribution should be at least 11% of the total outlay.

To ensure that private entrepreneurs bring in additional resources to the sector, not less than 60% of the total outlay for the project must come from sources other than Indian Public Financial Institutions.

Up to hundred per cent (100%) foreign equity participation can be permitted for projects set up by foreign private investors.

The condition of dividend balancing by export earnings which is normally being applied to cases of foreign investment up to 51% equity will not be applicable to foreign investments in the power sector.

The rates for depreciation in respect of assets have been liberalised.

With the approval of the Government, import of equipment for power projects will also be permitted in cases where foreign suppliers or agencies extend confessional credit.

The customs duty for import of power equipment has been reduced to 20% and this rate has also been extended to machinery for renovation and modernisation of power plants.

A five year tax holiday has been allowed.

The excise duty on a large number of capital goods and instruments in the power sector has been reduced.

Up to 16% return on the foreign equity included in the tariff can be provided in the respective foreign currency.

Fixed costs can be recovered at 68.5% PLF in case of thermal power plants and 90%. Availability Factor for hydel plants. Attractive incentives are prescribed for performance beyond these levels.

Tariff can be fixed in deviation of norms stipulated in the March, 1992 tariff notification provided that the per unit tariff does not exceed the per unit tariff worked out on the basis of the norms.

As a short term measure, the Government has announced the liquid fuel policy which permits use of certain hydrocarbon fuels for power generation subject to the project meeting certain location criterion.

To facilitate setting up of large capacity plants in the private sector, the Government has recently announced its Mega power project policy. The necessary support structure has been established to promote such projects.

State Governments have also been advised to consider setting up of barge mounted power plants to meet the immediate energy shortages for a short time.

The Government has also made efforts to streamline the process of project approval.

In order to encourage captive, including co-generation, power plants guidelines have been issued to the state governments for creating institutional mechanism for early clearance of such proposals and also to ensure effective measures such as purchasing or wheeling surplus power from such plants.

A4.1 Specific incentives for generating companies

- Normative parameters notified which, among other things, provide for 16% return on equity (ROE) at 68.5% PLF and up to 0.7% return on each incremental 1% PLF for thermal power plants.
- The tariff norms for Hydro-electric projects have been liberalised such as providing Capacity charge, incentive of up to 0.7% rise in ROE for each percentage point increase in availability of installed capacity beyond 90%.
- Generating companies operating coal based, gas based and hydro projects can sell power on basis of a suitably structured two part tariff.
- The tariff and other norms specified are the ceiling norms and allow Boards and Generating Companies to agree on improved norms.
- Premium raised by the Generating Company while issuing share capital and investment of internal resources created out of free reserve of existing company shall also be eligible for return of equity provided such amount is actually utilised for meeting the capital expenditure of the power generation project and forms part of the financial package approved by the Authority.

A4.2 The specific incentives for Licensees are:

- Licenses of longer duration of 30 years in the first instance and subsequent renewals of 20 years instead of 20 and 10 years respectively as it was before.
- Higher rate of return of 5% in place of the previous 2% above the RBI rate.
- Capitalisation of Interest During Construction (IDC) at actual cost (for expansion projects also) as against 1% over RBI rate as it was before.
- Special appropriation to meet debt obligations.

Table A4.1: List of Clearances required for power projects-detailed procedures

Sl No	Item	Agency	Remarks
	STATUTORY CLEARANCES		
1.	COST ESTIMATES Any power project involving capital expenditure exceeding the limit by Government Needs to be scrutinised by CEA for examination of salient features and benefits which may accrue therefrom	CEA	Required under Section of Electricity (Supply) Act. 1948
2	TECHNO-ECONOMIC CLEARANCE/CONCURRENCE OF CEA By CEA after examination of (I) River works/dams to be put up for hydro and for water availability for thermal plants (ii) Greatest possible economic output of electric power	CEA	Under section 30 of Electricity (Supply) Act. 1948 SEBs. State Govts Concerned Ministries of Coal Petroleum & natural Gas Railways Surface Transport involved.
3	PUBLICATION Schemes to be published in the Official Gazette/local newspapers as the generating company may consider necessary along with a notice for at least two months and modification if any consequent to public representation	State Govts	Section 29 clause (2), (3), (4) and (6) E(S) Act 1948 State Govts
4	WATER AVAILABILITY	1 State Govt	Interaction between State

		2 CWC	Govt Depts & CWC required Relevant Irrigation Act of the State & Central Water Commission
5	SEB CLEARANCE	1 SEB 2 State Govt	Sec 44 E(S) Act, 1948
6	POLLUTION CLEARANCE WATER AND AIR	State/Central Pollution Control Board	Water (Prevention & Control of Pollution) Act 1974 Air (Prevention & Control of Pollution) Act 1981
7	FOREST CLEARANCE	1 State Govt 2 Min of E&F	Coordination with State Forest Dept /Min of Environment & Forests (MOE & F) regarding Forest (Conservation) Act 1980
8	ENVIRONMENT & FOREST CLEARANCE	-do-	As per item 6 & 7 & Govt Policy in force
9	CIVIL AVIATION CLEARANCE FOR CHIMNEY HEIGHT	National Airport Authority	
10	REGISTRATION OF COMPANY	Registrar of Companies	Under Indian Companies Act, 1956
11	REHABILITATION & RESETTLEMENT OF DISPLACED FAMILIES BY LAND ACQUISITION	1 Min of E&F 2 State Govt	
12	HYDRO PROJECTS (MINI - MICRO)	Min of Water Resources	Under Relevant Acts
13	EQUIPMENT PROCUREMENT	DGTD	Import & Export Acts

	NON - STATUTORY CLEARANCES	
14	LAND AVAILABILITY	State Govt
15	FUEL LINKAGE	Department of Coal, Department of Petroleum & Natural Gas
16	FINANCING	CEA, Dept of Power, Dept of Eco Affairs, Financial Institutions
17	TRANSPORTATION OF FUEL	Department of Coal, Min of Petroleum & Natural Gas, Ministry of Railways, Shipping & Surface Transport

CWC	Central Water Commission
Min of E&F	Ministry of Environment & Forest
DGTD	Directorate General of Technology Development

Annex 5: Notes from interviews conducted during Trip A (14th October to 24th October 1997)

Summary of Meetings

Date	Personnel met	Type of Organisation
various	NS Prasad, Amit Kumar, Dr Kishore Mr Ahlivalia, Mr Ahalla TERI	Research Institute (subcontractors for project)
various	Dr Bakthavatsalam, MD Mr Rao, Solar Section Manager R.K.Vimal, Solar thermal Assistant Manager IREDA	Public financing
15th	Dr Ved Mitra and R S Sharma Solar Energy Centre	Government research station
16th	Dr Ahmar Raza, MNES	Central government
16th	C.M.Jain, Power and Energy Consultants	Developers
17th	Manish, REDA	Rajasthan State government agency
19th	Rajni Patel (Chairman) Sun Source (India) Ltd	Developer
19th	C.M.Trivedi Solar Power Corporation	Developer
22nd	Rahul Arora REPSO (USAID)	Financial
23rd	Vivek Bihani TDICI Ltd	Financial (venture capital), part of ICICI
23rd	Dr Erich Strijek KfW	German development financial organisation
23rd	Mr Ramaswami REC, Appraisal division	Rural Electrification Corporation (Central Government)

Dr Ved Mitra and R.S.Sharma, Solar Energy Centre, Gual Pahari, 15/10/96

Dr Sharma used to work for the RSEB and considers that they will not have any problems accepting solar electricity. Costs are the main barrier. Also the capacity factor. He is not convinced that Stirling Engines are a good idea for rural electrification, as leaks can be difficult. Better to use steam and a converted diesel engine, as in the Australian system. Then use batteries for storage if necessary.

Documents provided: Published papers by Dr Sharma

Dr Ahmar Raza, MNES, New Delhi 6/10/96

Currently no STP policy published by MNES, apart from that all technologies should be demonstrated. This is because there have been no fully demonstrated STP technologies in India. They are preparing a policy.

They have no stake in the Solar Chimney project in Rajasthan. Solar Energy Enterprise zone being set up in Rajasthan, aiming for 1000MW by 2005. REDA's role is that it will provide land for solar developments

Madhya Pradesh have also issued a tender for kW size plant. Tamil Nadu and Punjab are considering. MNES are encouraging states to come forward with policies.

In 1993, MNES put out a call for letters of intent for solar plant. 73 responses in all, 5 were serious. These 5 were relying too heavily on MNES financing, and negotiations have ensued. MNES want to specify results (a certain number of MW developed by a certain year, or penalties) and >60%PLF.

Wind: MNES purchased and tested some wind turbines up until 1990. Also did resource assessment and identified good sites. Then invited private parties to get involved. Difficult to do the same with STP, as more expensive.

Dish Systems were tried out, but not successful, as imported and no spare parts. e.g. 22kW dish from US jet propulsion labs.

Incentives for STP developments include 100% depreciation in first year; no sales tax; no excise duties. There are no formal subsidies There are no major barriers, only the low capacity factor.

Opportunities for STP in the industrial sector who currently have diesel captive power backup.

Mathania Project

As part of the restructuring of the SEBs, the Rajasthan State Power Corporation Ltd (RSPCL) has been set up as a wholly state government owned utility.

Implementation strategy not finalised, although the technology is finalised as the Solel technology. Then there will be a ICB. Unlikely to be a IPP. Likely to be RSPCL on a BOO contract. They will then have a ICB for supply only.

Many clearances are needed, e.g. from Ministry of Environment (but not from the Central Electricity Agency).

Dr Bakthavatsalam, MD, IREDA

IREDA is not involved with STP at present, as its focus is on commercialisation, not development. They will wait to the see the results of any demonstration installations (possibly for a couple of years of operation). Then they will decide whether to get involved or not.

The funding agencies involved will be:

- WB;
- Bilateral agencies;
- Indian Government;
- Private finance.

Mr Rao, Solar Section Manager, IREDA

IREDA follow the policy guidelines from MNES. They have no guidance yet. They don't normally deal with MW scale projects, as they don't have the funding for this. There is also a minimum project cost which IREDA is normally involved with.

IPP is best route for STP developments. 2 or 3 parties in India are currently looking at importing the Australian parabolic trough system.

R.K.Vimal, Solar thermal Assistant Manager, IREDA

IREDA currently only dealing with solar thermal systems up to about 100°C. They are interested to get involved in financing STP projects. However, they must be assured that their loan will be fully paid back. Their criteria for approval include test cases either in the country, or outside if accompanying R&D to prove it works in India.

Currently there is no policy from MNES. Technologies would have to be approved by the board of IREDA. Generally, the procedure is to have a test case. If this is approved, then the technology is approved.

Recent request to KfW and the Dutch government has included STP technologies IREDA are not involved in the solar chimney project.

C.M.Jain, Power and Energy Consultants (PEC), 16/10/96, New Delhi

PEC are involved in all types of power project. They have been looking at new technologies for both grid connection and decentralised.

They have been collaborating with the Australian's on their parabolic dish system. In fact, a company called Sunpower has been created to deal with this (same ownership as PEC). The system is a multi-faceted dish supported on foam, so no problem with cracking. Generates steam and can be connected together in parallel.

PEC recently persuaded GEF to part fund a 10MW plant (20-30% GEF grant financing). They have approached MNES for further funding, but they are still to decide.

He said that stirling engine lifetimes are low, working gases are difficult to get to remote areas etc. Their system uses normal boiler tubes and hydraulics which are available in-country. Only 92% reflectivity glass available in India. A 2 directional rotating joint is needed, and would be imported at present

The steam output from this plant varies in quantity and quality. Ideally, the quality remains good, and only the quantity changes.

Also O&M advantages, as, unlike with troughs, they are in parallel, so if one unit fails, the system can still operate. Cleaning is by hand, at night.

They have also investigated the possibility for a combined system with the waste heat being used for desalination. Especially good on small islands. Also looking dissociating NH3 to H2 for storage.

Mr Manish, Rajasthan Energy Development Agency (REDA), 17/9/96, Jaipur

In 1983, when MNES set up, state RE boards were also established to implement and monitor projects. They receive an annual budget from the State Governments, and /or overseas governments.

REDA are involved in the Mathania project, as are MNES. Equity 10% Raj government, 10% central government, 20% IPP/developer. Details are not finalised. Parabolic trough likely to be specified in a ICB for the whole installation. Likely to be baseload plant. Solar data currently being collected by CAZRI.

DPR prepared by EIL and Solel, with Fichtner Annex. EIL selected by Rajasthan government. Opinion now is that it is unlikely to be BOOM, more likely to be an order for supply from the implementing agency. Supplier will be expected to invest equity in the plant, and therefore will have interests in its operation.

Could be implemented and operated by a new concern: Rajasthan Electricity Power Corporation Ltd (set up as part of the restructuring, but essentially part of the state government).

REDA have recently issued a call for proposals for solar IPPs in the West, and have signed 3 letter of intent for BOOM projects with:

Amoco/ENRON	50MW PV
Sunsource	50MW concentrating PV
ENERGEN International	200MW solar chimney

Tariff structure set, starting at 2.25 Rp/kWh (4p/kWh).

This call is open and can effectively be applied for by anyone who can meet these tariffs. Applications are to REDA who pass them on to the state government (who must approve all BOOMs). RSEB is only involved as far as the PPA is concerned.

State incentives for solar technologies include exception from import duties, and exception from sales tax.

The call for proposals is not applicable for decentralised applications. These still have to be controlled by the SEB, and tariffs are set by the Rajasthan government. Tariffs are set at about 0.4 Rp/kWh for consumers. Typical coal plant generation costs around 2Rp/kWh.

Rajni Patel (Chairman) & S.Trivedi (Manager), Sun Source (India) Ltd, Ahmedabad, 19/10/96

Sunsource have a PPA with Rajasthan State Government for a concentrating PV plant using a Fresnel lens (100 X concentration). They are planning to import US technology, although this will be the subject of a call for tender. They have applied to IREDA for loan, and are planning to apply to WB and other foreign funds.

They are not that interested in STP, as their eggs are currently in the PV basket. Only interest may be in combination with the concentrator PV system, as will need a cooling circuit anyway

C.M.Trivedi, Solar Power Corporation, Ahmedabad, 19/10/96

Most of their work is related to process industries, so their STP development has been mostly with process steam in mind (100 - 200 °C) They have collaborated with Dr Rao and associates.

The system they proposed to PACER was a square parabolic dish based on a 50kW prototype in New Mexico developed by Power Kinetic This generated steam and used a steam engine developed by an Australian university which is basically a modified diesel engine This US research ran out of funds

Most of the components in this systems are used widely in other industries, as the glass facets are flat. 90% reflectivity mirrors are currently available in India. Receiver can be manufactured in Bangalore

Their plan is to install a small demonstration unit in India to prove the concept. Approximate R&D costs are 65-70,000 Rp/m2

They are convinced of the market, for instance in the textile industry, which needs steam at >170oC. They get enquiries for systems but have no pilot to show people.

Rahul Arora, Renewable Energy Project Support Office (REPSO), New Delhi, 22nd October 1996

REPSO are part of the USAID RE Commercialisation Project (RECOMM). PV and emerging technologies are included in this programme.

REPSO can offer loans for scaling-up activities, but they need references from customers, bankers etc. As a result, they cannot really deal with un-proven technologies. Only interested in proven, commercially viable technologies. This means commercially viable WITHOUT subsidies.

They can offer two types of support

- Conditional grants at 12% IRR, repayable only if there is commercial success;
- Cost shares with industry for studies. If the project goes ahead, the loan is repaid.

Meeting with Vivek Bihani, TDICI Ltd, New Delhi, 23/10/96

ICICI is a development financial institution, handling private and public funds, which can supply loans. TDICI supplies venture capital (equity). As such, they look for investments short gestations (max 7-8 years, better 4-5 years) when they can dis-invest. As such, they obviously look at proven technologies in a developed company with a good track record, client base, recommendations etc.

They look for investments with potentially unlimited returns. As such, any project involving a PPA is not going to be eligible for venture capital financing.

There is a Technical Group within ICICI which presently handle some WB funds for development of technologies and commercialisation.

PACER: recently had a small amount of funds to keep going from the WB. They can offer conditional loans for max. 75% of costs to a consortium, only repaid if commercialised.

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They can offer two types of support.

- Conditional grants at 12% IRR, repayable only if there is commercial success;
- Cost shares with industry for studies. If the project goes ahead, the loan is repaid.

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PACER: recently had a small amount of funds to keep going from the WB. They can offer conditional loans for max. 75% of costs to a consortium, only repaid if commercialised.

Work must be innovative and capable of commercialisation within 5 years. Part of the consortium should be a profit making company which must contribute 25% of costs.

Also offer grants to research institutions for work relating to consortium work. Also offer general grants for R&D work.

TECHNICAL INSTITUTIONS PROGRAMME:
$40 mill from WB. Activities such as setting up pilot plant, technical collaborations, training and exchange programmes. Offer loans to technical institutions (like TERI) at 0.25 %, 15 year payback. Contributions expected from TI.

SPREAD:
Loan to companies who want to manufacture a new technology. They tie up with a research institution and try it out with pilot plants. The company must have the intention to take it to commercialisation. 6% during development, 15-16% once commercialised. Company must contribute at least 50% of costs.

Lending agencies will require the following information before offering credit:

☐ Security
☐ Will only lend a % of total (fixed asset recovery)
☐ Viability
☐ Is this the best technology for the job? i.e. cheapest.
☐ What are the alternatives?
☐ Long term future.

Erich Strijek, KfW, New Delhi, 23/10/96

They have been involved with Mathania from the beginning, both as funders and as technical assessors (in co-operation with MNES, but this is a standard activity, to assess their investments).

in '89, they financed a study by Luz and Fichtner for a 30 MW plant. Identified finances as the main problem. Eventually, this stalled as the Indian government couldn't decide who would deal with it.

In '94, Indian government commissioned EIL and a French organisation to do a very similar study. KfW approached for funding. They commissioned Fichtner to do some more work and look at options for a hybrid plant. (There was also some work done on a smaller installation retrofitted onto an existing NTPC thermal plant as a pilot, but NTPC didn't take it up.)

Result was a small cost difference hybrid system GEF funding achieved. KfW 250 million DM partly soft loans, partly commercial loan.

Currently awaiting government decision as to who will implement the project.

KfW intend to continue to be involved in STP technology after Mathania. They are not sure if IPP is the best route for demonstration plant.

Mr Ramaswami, Appraisal division, Rural Electrification Corporation (REC), New Delhi, 23rd September 1996

They have no experience with STP at present

So far, RECS activities have been grid extension Now they have electrified areas close to the grid, and are left with the most remote areas only They are interested in decentralised systems for these situations, and the appraisal division has been set up recently to look at these alternatives. Particularly interested in hybrid systems, and mini grids which can later be connected to the main grid.

The scale of the market is unsure, and they are looking for funds / outside consultants to carry out the assessment. Probably between 20 - 80,000 villages Most cannot afford any capital cost. Also maintenance may be difficult with unskilled labour However, a minority consists of industries currently shipping in diesel at great cost

Up until now, REC are given money by government, and they then pass this on (as a loan) to SEBs to implement and operate SEBs given targets in terms of no. of villages to be electrified, but not necessarily which ones Now starting to look at private involvement, but distribution and transmission would still be by SEBs under current legislation. Currently drawing up guidelines for private involvement No formal policy on Renewable Energy yet.

States have recently produce guidelines for private RE generators, but mostly for SPV, not large scale solar. These included provision for 'banking' power (generating and using at another time, most developments are for 'captive' power), and wheeling PPA format is not really finalised in India yet, and few PPA have been signed.

First priority is to assess villages and come up with guidelines on optimum systems to use. Then pilot projects. They need outside funds / assistance for both these tasks.

They have a memorandum of understanding with an Australian company (AES), a University and CASE for pilot decentralised schemes, mostly using PV, but also other hybrids.

Annex 6: Review of recently published STP market predictions and support strategies

A6.1 The EC Strategy For Solar Thermal Energy: Research development and Industrial Application, EC JRC, December 1996

A6.1.1 Objectives

- Develop a European STP industry which can reduce the rate of depletion of fossil fuels, and be an important clean-energy option for producing electricity.
- Develop the technology and reduce costs so that market forces alone will support the industry by 2010 (i.e. the costs of generation are reduced to the selling price and subsidies no longer necessary). Utilities can use their normal methods of attracting investment funds to construct STP plants.
- To put European Industry in a lead role in this market
- To develop markets in sun-belt countries for export and transfer of European technologies

To achieve these objectives, the following short term actions are required.

- Scale-up and improve the technology
- Create a commercial market, with suppliers, customers, financing and personnel experienced in designing, building, operating and maintaining these plant

Political leadership and funding from EC is proposed, to catalyse a co-ordinated effort involving international funding agencies, national governments and the private sector.

A6.1.2 Market Prediction

Assumes a mature and competitive industry by 2010, the world market is predicted to be 5.1 GW per year during the period 2010 to 2015. This represents an investment of US$ 10 billion per year, and includes 800 MW per year in India.

Figure A6.1 indicates how the costs are predicted to develop up to 2010.

A6.1.3 Barriers to commercialisation

The following barriers to commercialisation have been identified:

- Lack of competitiveness
- Lack of financial and tax incentives (these have been used to great effect to build up a wind industrial base)
- Subsidies of fossil fuels or electricity in some countries
- Environmental costs are not fully charged to the users
- Property taxes can fall more heavily on high capital cost plant (such as renewable energy technologies)

As a result, investments in STP are currently unattractive for utilities and IPPs.

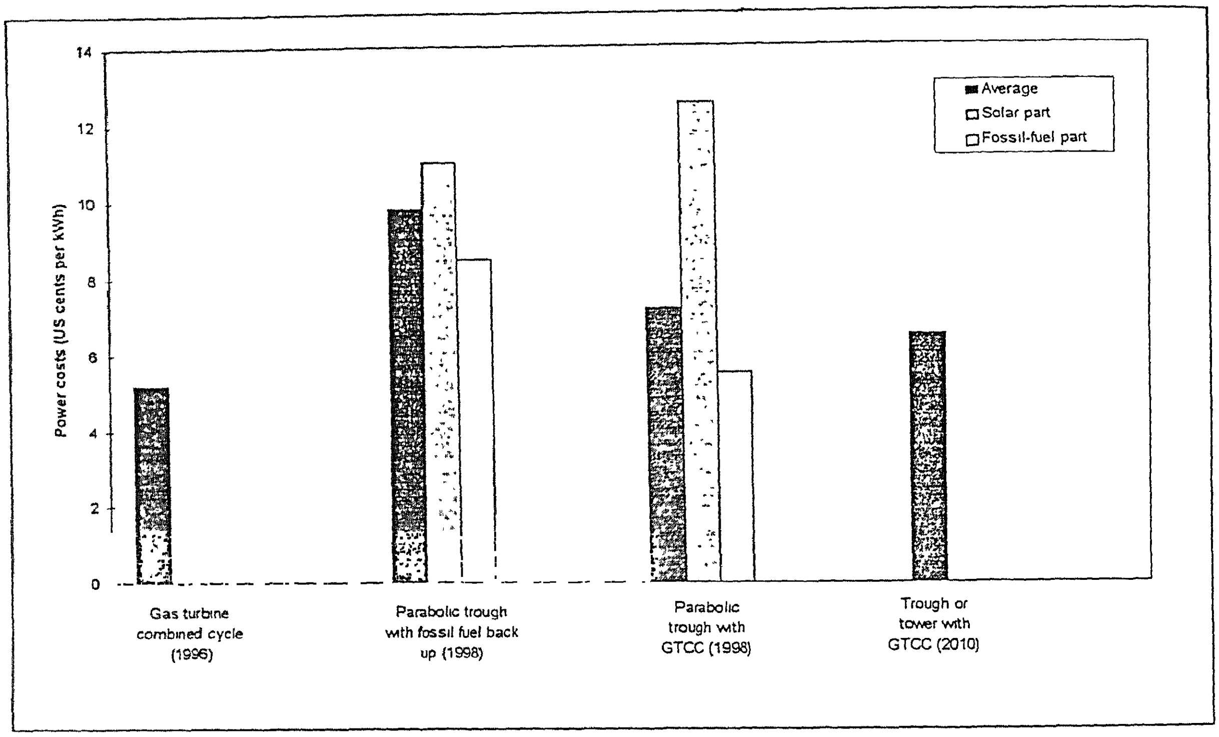

Figure A6.1: Comparison of power costs, current and advanced STP technologies (I.Spiewak 1996)

A6.1.4 Proposed Actions

A Construction of 2 to 5 solar demonstration plants
- Within EU territory or Mediterranean countries
- Focus on improved hybrid plants, repowering old steam plants and direct steam generation
- Solar part should be at least 2500 hours per year and 10MW

B. Continue R&D development, for example in the fields of:
- ☐ Innovative mirror systems (account for 30 to 40% of costs)
- ☐ Simpler and more efficient heat transport schemes (such as DISS)
- ☐ Higher temperature and more efficient receivers and power cycles (e.g. Brayton)
- ☐ Novel optical systems (such as beam down power towers)
- ☐ Improved integration of STP into hybrid plants
- ☐ Economies of scale and factory mass production
- ☐ Thermal energy storage systems

C. Construction of commercial plants
- 30 to 100 MW, some in Europe, some abroad (e.g. Southern Mediterranean)
- Hybridised with GTCC
- Annual availability greater than 90%, solar fraction > 50%
- In close co-operation with host country to promote technology transfer
- Promote competition between STP technologies
- Utilities to be involved, providing management, operations know-how and perhaps equity
- Training of operators in European facilities

A6.1.5 Costs and financing

	Total costs (US$)	Public contribution (US$)
Demonstration plants	12 to 120 million per plant	12 to 60 million per plant
R&D	-	Expanded DG XII programme
Commercial plants	120 to 300 million per plant	40 to 120 million per plant

The total public funding over a period of 12 years would be US$ 850 million. These costs would be shared among a number of international and national sources, including national governments, the EC, and international funding agencies

The commercial projects are likely to include financing from international, regional and national export-import banks, and the private sector

A6.2 European Renewable Energy Centres Agency (EUREC)

In 1996, the EUREC Agency published a book entitled "The Future for Renewable Energy: Prospects and Directions". This included a section on solar thermal power stations. Table A6.1 is a summary of the objectives for technical development of key components and systems.

Table A6.1: The essential component and subsystem objectives for improvements

	2005	2025
Parabolic trough	cost goal < 12 cents/kWh	
Collector/Receiver Improvements	Concept Optimisation and Application	
Power Blocks up to	200 MW$_e$	
One Cycle for Heat Transfer and Prime Mover by Direct Steam Generation	Demonstration Plant and First Commercial Unit	Commercial Units
Combined Cycle	Demonstration Plant and First Commercial Unit	Commercial Units
Central Receiver (Tower)	**cost goal < 12 cents/kWh**	
Molten Salt for Heat Transfer and Storage	Demonstration Plant	Commercial Units
Volumetric Air Receiver with 90% efficiency	First Commercial Units	Commercial Units
Power Blocks up to	200 MW$_e$	
High Temperature (600 to 700°C) Storage (Thermal or Chemical)	Development and Demonstration	First Commercial Unit (Chemical)
Combined Cycle (e.g. Water/Steam: SOLGAS)	Demonstration Plant and First Commercial Unit	Commercial Units
Parabolic Dish	**cost goal 18 cents/kWh**	
Power Farms up to	100 kW$_e$ and 1MW$_e$	Commercial Units

Heat Pipe Sodium Receiver and Hybrid Firing	Development, Demonstration and First Commercial Unit	Commercial Units
Turbine Applications	Development, Demonstration and First Commercial Unit	Commercial Units

The market in the Mediterranean region is estimated to be 3.5 GW_e in 2005 and 23 GW_e in 2025.

The strategy developed by the EUREC agency involves demonstration of existing technology in the Mediterranean area, together with technical research on the next steps (as detailed above).

A6.3 IEA Solar Thermal Power and Chemical Energy Systems (SolarPACES)

In 1996, SolarPACES published their strategic plan with the goal that STP technologies will make a significant contribution to the delivery of clean, sustainable energy services in the world's sun belt by the year 2010. This strategy focuses on the following 3 objectives:

- Technology development (their prediction is that costs reduction will ultimately lead to prices as low as 5 US cents per kWh);
- Market development to reduce financial, political, market and institutional hurdles;
- Expand awareness of the potential of STP to address the energy and environmental problems that the world faces.

SolarPACES identify the following non-technical barriers to the commercialisation of STP technologies:

- Energy market de-regulation and low energy prices, increased emphasis on the least-cost power option, whilst ignoring the environmental costs;
- Uncertainty about the costs, performance and reliability amongst industry and financial community;
- Perceived risks of high capital cost projects;
- Legislative and regulatory barriers;

A6.4 Pilkington Solar International

In 1996, Pilkington Solar International published their Status Report on Solar Thermal Power Plants. They estimate the potential STP market to be in excess of 250 GW by 2010. However, they accept that STP will not fully penetrate the market, so actual installed capacity will be much smaller than this Table A6 2 shows the assumed market penetration up to 2020.

Table A6.2: Market penetration

Period	Installed capacity (GW)
2001 to 2010	14
2011 to 2020	30

ANNEX 7

International Workshop on Solar Thermal Electricity Generation in Developing Countries
at
Hotel Taj Palace, New Delhi
on
March 1, 1997

SUMMARY

The workshop was jointly organised by TERI and I T Power Ltd. Under the sponsorship of ODA (Overseas Development Administration), U K.

Agenda

9.00-9.30 Registration

9.30-10.00 INAUGURAL SESSION

Inaugural Address - *Dr. R K Pachauri, Director, TERI*
Opening remarks - *Mr. Anthony Derrick, Director, IT Power Ltd., U K*

10.00-10.30 Tea

10.30-1.00 TECHNICAL AND POLICY SESSION

Chairperson . Mr. Ajit Gupta. Advisor, MNES

Historical developments and current state-of-the-art
Solar Thermal Electricity Technologies
Prof Steve Kaneff, Head of Energy Research Centre
Australian National University

Current policies on Solar Thermal Electricity
development in India
Dr. Ahmer Raza, Director, MNES

Some issues concerning utilization of Solar Thermal
Electricity for Rural Electrification
Mr. A Anantha, Chief (Appraisal), REC

Presentation of technical and policy results
from the ODA-FUNDED project
Mr. P Raftery, Project Engineer, I T Power

1.00-2.00 Lunch

2.00-4.00 FINANCING SESSION

Chairperson : Dr. B S K Naidu, Executive Director, IREDA

Presentation of economic and financial results
Mr. Sanjeev S Ahluwalia, Senior Fellow, TERI

The aid financier's perspective
Mr. U Goretzki, Vice President, India Regional Dept., KfW

The private sector perspective
Mr. C M Jain, President, Power & Energy Consultants
Mr. C M Trivedi, M D, Solar Power Corporation

Financing Projects in Solar Thermal:
A Non-banking Finance Company's perspective
Ms. Maria Kunder, Account Manager (Renewable Energy Finance)
Tata Finance Ltd.

4.00-4.30 **Tea**

4 30-5.30 PANEL DISCUSSION

"Future strategies for solar thermal electricity generation in developing countries."

Chairperson: Dr. E V R Sastry, Advisor, MNES

Short summary of Proceedings
Mr. Anthony Derrick, Director, I T Power Ltd.

Panelists:

Dr. E V R Sastry, Advisor, MNES
Mr. Anthony Derrick, Director, I T Power Ltd.
Prof Steve Kaneff, Australian National University
Dr. V V N Kishore, Senior Fellow, TERI

Vote-of Thanks: *Mr. Amit Kumar, Fellow, TERI*

Inaugural session

Dr. R.K. Pachauri, Director, TERI welcomed all participants to the workshop. He complimented the ODA for the initiative they have taken in the field of solar thermal energy generation. He mentioned that TERI and IT Power were having long partnership in the past.

He said that in India, there is immense potential for solar energy utilization thus it is of enormous importance for science and technology community to develop small decentralized system, e.g., water desalination. India is extremely well placed to take leadership in the solar thermal areas not only because of high radiation levels but also, the huge market availability gives economy of scale in production. It is hoped that this workshop will be starting point of some major activities of the solar thermal area The ministry of Non-conventional Energy Sources is also very closely associated with this activity He said that from the outcome of this workshop, we would be able to come up with a strategy, which would require involvement of MNES, industries, research and academic institutions and also international community. It is extremely heartening from this perspective to have distinguished experts, experienced professionals from other countries taking part in this workshop

Mr. Anthony Derrick, Director, I T Power Ltd informed briefly about the study undertaken by IT Power and TERI for British ODA, investigating status of solar thermal electricity generation technologies. The team is trying to assess what is the prospect, what strategies should be formulated to develop and improve commercialization and dissemination of solar thermal technologies.

He further said that in this workshop, it was expected to have debate on barriers to the technologies; identify those barriers and formulate strategies to overcome those barriers and create awareness about the technology As we have distinguished people from MNES, financial agencies, and policy organizations, the outcome of the discussion will have an impact and will help to arrive at policy and technical conclusions in the report prepared by IT Power and TERI which will be submitted to the ODA Further, this report will help ODA to decide where to support the technologies. In addition, IT Power is working with European Commission, which has prepared a strategy document on solar thermal energy generation, and experts meeting is scheduled. The conclusions of this workshop will be put for consideration in this meeting.

Technical & Policy Session

Chairperson: Dr. Ajay Mathur, Senior Fellow, TERI / Mr. Ajit Gupta, Advisor, MNES

Prof. Steve Kaneff, Head of Energy Research Centre, Australian National University gave presentation on 'Historical developments and current state-of-the-art solar thermal electricity technologies'. He said that the Energy Research Centre at the Australian National University was working on solar thermal power generation since 1971 and studied whole range of possibilities and concepts and has experience with field installations. He said that discontinuity in support and availability of fossil fuels led to less progress over a period of time. The scenario started changing with oil shock in 1970. The Australian National University and Energy Research Centre have continuity in funding and determination. They started with main technologies in 1979. He gave brief working principles of central receivers, solar chimney and parabolidal dishes. After looking into all the technologies, they decided to focus on dishes as they have higher efficiencies and attain higher temperature thus have advantage over other technologies. 25 kW plant using a parabolidal dish was demonstrated with all necessary control features followed by another plant in collaboration with an US firm for Department of Energy, US. The Centre constructed a big dish of 400 m^2 area with double axis backing. The purpose was to build a collector which can be used in large numbers to produce high quality steam to run power systems. He proceeded to show difference between concentrating technologies, central receiver, flat plate collector, parabolic trough and, conical concentration etc. and their concentration ratios and temperature ranges. It showed that sun tracking parabolidal concentrator has high efficiencies, attains higher temperatures and so they concentrated on dish technology. Their belief in dishes was confirmed by the economic benefit which he explained by comparing system efficiencies, capital cost, levelised cost and operation and maintenance cost for parabolic trough, central receiver and parabolic dish. This points to potential benefit of high temperature collectors. Then he showed the Mac 1 collector of 400 m^2 area with tracking mechanism. The performances of dishes indicate that they should be taken seriously. The temperature achievable at focal point of the dish is 1500°C, thus number of different processes are possible, e.g., conversion of heat to chemical energy.

He also presented the economics for different concentrator technologies - parabolic trough, central receivers, solar chimneys, and dish sterling. The factors used to compare between 80 MW and 1 MW systems were annual radiation, storage capacity, collector area, land use, operation cost, capital cost and for 30 years life of collectors. The outcome was as follows for 80 MW.

	Electricity cost cents/kWh	area m^2	efficiency
Parabolic troughs	14	470,000	15%
Central receiver	14	409,000	14%
Solar chimney	20	8 km^2	1%
Dish with backup	7	262,000 m^2	27%
Dish without backup	7.09		26%

It shows that dishes are much more efficient. There is also economy of size for parabolidal. The cost reduces approximately as follows:

2 MW	10 MW	20 MW	100 MW
20 cent/kWh	11 cent/kWh	8 cent/kWh	7.5 cent/kWhr

He emphasized that the other technologies also had their place. Then he presented the summarized results of various studies undertaken. For a 2 MW dish, the levelised electricity generation cost at the solar insolation levels of 2400 kWh/sq. m per annum, is below 10 cents/kWh. For a 20 MW dish, cost of electricity drops by 50% compared with 2 MW dish. Further, if 2 MW dishes are used with 100 MW steam turbine, again at same insolation level, i.e., 2400 kWh/sq. m per annum, the electricity cost goes down to 4 cents/ kWh.

Mr. Pramod Kulkarni, *CEC* (California Energy Commission) talked about the policy experience they have in renewable energy technologies. CEC is a policy and planning body in California. Mr. Kulkarni is associated with the department of research and development and commercialization of technology. The policy initiatives by CEC created substantial amounts of awareness in renewable technologies and increased contribution of power from renewables from almost nil in 1971 to 6000 MW in 1992. To get this done the price is paid in terms of tax holidays, tax credits and accelerated depreciation. But now policies are changing, in the initial years there was a thrust to initiate the process, to develop confidence in financiers, utilities and users. That being done the objective today is to find out that how these technologies can be made sustainable. The development of solar thermal has stopped today in California, not because of failure of technology or economic non-viability but the issues which are external to technology have impinged on its development and led to its starvation. In the beginning, the promise of buying power at a guaranteed rate, which is extremely critical, created the atmosphere for fast growth of the renewable technologies. The developer was given guaranteed price for capacity and power for 10 years, and those prices were quite high thinking that there will be shortage of oil and prices of conventional power will go up. Combined with this view, as a policy body, CEC was interested in diversification and broadening of base and also in environmental benefits of renewables Lucrative incentives were given for renewable power developer. The government has given $200 million tax credit to solar thermal electricity generation and thus a reliable source was established which can be used in case of gas or oil shortage. He also mentioned that an electrical unit from this technology is more valuable in comparison with convention power plant as it meets peaking demand. From environmental perspective also, the electrical unit from conventional power plant at peak cost more than solar. Thus it not only is a cheaper source of electricity but less polluting at that time of the day.

The scenario today in U.S. is that there is major movement for privatization, in fact a legislation is passed forcing technologies to compete in an open market. Since 1991, there are no developments in solar thermal field not because of doubts about the technology but because of doubts to find the market for the electricity produced Its not only solar or wind has come to a standstill but the conventional technologies are also coming to stand still as they don't know where the market will be. The market in California is driven by natural gas, and the gas prices are extremely low today. The rates of power were down to 3-4 cents/kWh from 14-13 cents/kWh. It is due to this it is difficult to stress on new developments in solar thermal power.

There are ways to improve upon the technology and CEC would like to support it. A study has been carried out by Sandia National Laboratory for US Department of Energy to identify where improvement can be done. It has suggested improvements in operation and maintenance with which it is expected that the O&M cost will come down by 30-35%. Also with suggestions received from the Sandia National Laboratory, the capacity factor is also expected to improve. These improvements will bring the technology in the competing mode.

The situation today is that they do not have any tax credits. The government policy should be consistent as on-off policy hurts the development in the long run. The infrastructure development is also important to give comfort level to developer. The efforts are now to create atmosphere, with consistent policies He said that California would like to see more solar thermal plants, but it cannot do the technology development alone. It is very important that other countries especially the developing countries also participate. He concluded with saying that the policy is to help technology to bring down O&M costs but no more capital investment.

Mr. Ahmer Raza, Director, Ministry of Non-conventional Energy Sources presented the current policies on solar thermal electricity generation in India. He said that so far the emphasis has been on decentralized systems The objective of solar energy programs is to carry out resource and technology assessment to carry out research and development in solar technologies, to develop local capacity and industrial capability to promote commercial projects.

MNES is now planning to construct a 140 MW solar thermal power plant at Mathania. It comprises 35-40 MW generation from parabolic trough solar concentrators and 105 MW conventional power generation. BHEL has prepared a detailed project report for solar part Government of India is giving $15 million, the government of Rajasthan is helping it providing grant and loan, the World Bank and KfW are also providing a grant and concessional loan. This project will be implemented by Rajasthan State Power Corporation Ltd., which is formed exclusively for this project. It will implement, own and operate it. In order to encourage emerging solar technologies, Solar Energy Enterprise Zone has been established by government of Rajasthan in the districts of Jodhpur, Jaiselmer and Barmer. Government of India is also supporting the Rajasthan government to establish this zone. Main objective of it is:

To support sustainable development of cost-effective solar technologies.

- To create a comparative framework for solar thermal power plant using different technologies.
- To establish self sustaining and techno-economically viable solar energy production facility.
- To provide special promotional incentive to support private sector interest in this area.

A target of 1000 MW generation by 2010 through solar energy has been set for Rajasthan. The Rajasthan government has taken initiative on its own, and started procedure for installation of 300 MW power plants on commercial basis, the land has been allocated to different parties, power purchase agreements have been signed. A feasibility study is planned for large central receiver project and R&D program for collector development is planned.

The estimated power generation by end of eighth 5-year is 1400 MW which is 7% of total capacity addition in the same period. For ninth 5-year plan, total generation target is 3000 MW. This comprises wind: 2000 MW, biomass: 450 MW, small hydro: 350 MW and solar: 150 MW.

IREDA is corporate financing agency of MNES. He gave brief information about IREDA, its interest rates of different renewable sectors. Till September 30, 1996, IREDA has sanctioned loans amounting Rs 1188 crores, out of which 585 crores were actually dispersed. IREDA had net profit of 7.5 crores and 84% recoveries rate. The resource mobilization for IREDA has been done through World Bank, GEF, Asian Development Bank with equity from Government of India and market borrowing.

He stated that there was a great potential for solar thermal power generation in India and the Government would be providing all incentives for its promotion.

Mr. A Anantha, Chief (Appraisal), REC (Rural Electrification Corporation Ltd.) shared his views on issues concerning utilization of solar thermal electricity for rural electrification. He said that lot of work could be done for utilization of this technology in rural areas. REC's objectives were promotion and financing small mini-micro generation projects, decentralized generation and distribution schemes for SEB's, NGO's, corporate and private sectors etc. In this connection, REC has taken a major policy decision to fund power generation projects. He informed about the schemes for financing, one is for decentralized generation plants and another for normal commercial plants. He mentioned that REC did not have those funds which can be utilized for solar sector at concessional rates. In renewable energy technology, 40 projects have been sanctioned mainly in mini-micro hydro, wind and photovoltaic areas. The status of village electrification in India is that 85% of villages have been electrified. The options for electrification of villages are extension of conventional grid and decentralized generation and distribution with renewable energy technologies locally. The deciding factors for choice of village electrification are distance from the grid, availability of a local energy source, economics of cost of electrification, demand and potential, delivery cost, environmental considerations and maintenance. The least cost option can be worked out vis-a-vis grid extension. The consumers in rural area prefer conventional grid power for is reliability, quality of supply, power cost and scope of extension. Here he also mentioned that definition of village electrification has to be reviewed.

He then gave some fundamental aspects of solar energy and its availability in brief. The important components of solar thermal electricity system are collectors with reflectors, receiver, tracking mechanism etc. which is major part with energy transport, energy conversion and energy storage. A variety of systems for collection of solar radiation are being pursued like parabolic troughs, parabolic dish and central receiver etc. with different modes of energy transport, storage and conversion. He further classified the solar systems into low, medium and high temperature cycles with flat plate collectors, parabolic collectors and central receivers respectively. Compared to coal fired power plant, solar plant requires less land. While a solar plant does not require any fuel, it does require higher construction and maintenance work.

The energy requirements in rural areas are in the form of cooking, heating, lighting, drying and for electrical/electronic appliances. For village electrification through solar thermal route, there must be sufficient availability of water, sufficient solar insolation, lands and for night operations, alternative biomass fuels to improve systems PLF The basis for working out requirements is:

- Small size plant for local villages: less than 100 kW but their economy is a question
- Medium size plants for block-wise: 3 - 5 MW
- Large plants district-wise: 50 - 100 MW

Then he described the benefits of solar systems as

- Non polluting, free from CO_2 emissions,
- Direct use of solar heat can be undertaken without conversion to power for meeting many energy needs.
- It restricts degeneration of forests by reducing the wood consumption in rural areas

But there are also limitations to this technology and they are high installation cost, adequate water requirements, variation due to day-night cycles and, difficulty in installing them. The suggested steps, put forward by him were

- A national survey and investigation to assess load requirement, land requirements, future load growth and, affordability etc.
- Training of local manpower for O&M
- Design and selection of optimum size of plants
- System reliability should be studied
- Setting up of pilot schemes before taking up commercial operations
- International grant assistance for grounding pilot projects and further low costs funds for commercialization
- Capital cost to be supported by Government.
- Development of software for design of solar system
- Sufficient funds to be earmarked for continuous R&D efforts.

Mr. Peter Raftery, Project Engineer, IT Power Ltd. presented the technical and policy results from the ODA-FUNDED project on assessment of Solar thermal electricity (STP) use in developing countries. The objectives of this project were

- to identify important issues
- to set agenda for future developments
- to raise awareness of potential of solar thermal electricity and dissemination of results.

It was told that at the end of project, the guideline document on solar thermal electricity will be published. The scope of the study includes all technologies, both grid connected and smaller plants with India as case study. In this project the technologies are reviewed with their technical implications and the present workshop is also a part of activities under this project. The technical implications studied were:

- electric supply and demand factors with timing issues.
- electrify interface requirements common to all technologies in country manufacture
- operational economics

- operation and maintenance
- criteria for site selection in terms of water supply, proximity to the grid etc.
- land use
- environmental impacts - benefit assessment with impact of heat transfer fluid used.
- safety and decommissioning.

He presented supply and demand factors in India - mainly peak, electricity capacity deficits in terms of capacity and supply amount with peak demands in morning and evening. The plant load factors are average 60% with T & D losses amounting to 22% in 1993

More than 50 Indian companies were identified with potential for manufacturing of different components required in solar plant like concentrators, absorber coatings, reflector material, the generator and, electrical controls etc. The problem came with specialized components, e.g., high reflectance glass with 98% reflectivity. But given sufficient market in India, all components can be manufactured.

Citing an example, he told that the operation and maintenance of a 30 MW central receiver plant require 33 full time staff. The O&M costs of 2 US cents/kWhr could be reduced to 1.4 US cents/kWhr with further research. The issues related to O&M are: training, establishment of O&M programme, technical support to keep plant running, supply of spares and commitment from spares suppliers, which was not there in past

The land use implications are

- social implications eg. population displacement as large area is required
- environmental implications
- the land uses depend upon solar resource availability and plant capacity etc.

He said that the ideal location is the area of poor soil quality and low population density. He informed about a survey for institutions assessment which was carried out in October 1996. It included existing power infrastructure, rural electrification, captive power and financing, risks, and lessons learnt vis-a-vis independent power projects.

He also discussed about the EC strategy regarding the solar thermal energy. The objectives are reducing environmental impacts and slowing down of depletion of fossil fuels. The target is to make this industry competitive by 2010 with European industries in lead role and developing market in sunbelt. The strategy adopted for this is to scale up and improve technology to create a commercial market of 5.1G W/years by 2015 and for India 800 MW power annum. The financial requirement is the tune of $10 billion per year aiming to bring down solar thermal electricity prices to 6 US cents/kWh (at this price market can sustain). It requires coordinated efforts from international funding agencies, national governments and private sectors.

The proposed actions are to develop 2 - 5 demonstration plates within EU territory or Mediterranean countries with a focus on hybrid plants; repowering old steam plants and direct steam generation. It is also proposed to continue the R & D in this field. It is decided to construct commercial plants up to 30 MW /100 MW hybridized with GTCC.

Under market development initiatives comes GEF (Global Environment Facility) to provide grants and concessional funds to developing countries for projects which protect the global environment and providing grant for uneconomic portions of the plant.

Financing Session

Chairperson: Dr. B.S.K. Naidu, Executive Director, IREDA

Mr. Sanjeev S. Ahluwalia, Senior Fellow, TERI made a presentation on an economic outcome of 'Development of solar thermal electricity generation in developing countries', TERI-IT Power joint project. It consisted of financial analyses of different solar thermal power generation technologies, both in centralized and decentralized mode

In the beginning, he mentioned about the cost data limitations as some of the technologies are not used in real sense and some are speculated values. Then he showed cost comparisons of decentralized applications of four solar thermal electricity generation technologies, namely a parabolic dish (capacity 50 kW and 1 MW), solar pond (capacity 5 MW), central receiver (capacity 2 MW) and conventional decentralized diesel generation The factors taken into account were capacity utilization factor, capital cost and, levelised cost. The analysis excluded environmental cost, subsidies and tax. The levelised cost of solar thermal generation was quite high, in the range of Rs 10/kWhr for 50 kW dish to Rs 5/kWhr for 1 MW dish He said that the difference between costs of conventional and solar power needed to be paid either by preference to solar thermal technologies or in terms of avoided environmental cost. The financial analysis for centralized solar systems shows similar trends, with solar thermal power generation cost higher than conventional generation costs. The 25% solar with combined cycle natural gas generation cost is also high - Rs 3.5/kWh compared with gas turbine generation cost of Rs.1.5/kWhr

But it was pointed out that it is not really enough to compare decentralized solar thermal generation with a decentralized diesel generator because:

- India is a diesel scarce country and
- Diesel prices are not at really economic value as they are controlled by government

Thus, the comparison with delivered cost of power by extending the grid to the remote location should also be done. The comparison with extending the grid is done by taking lowest cost of conventional power generation @ Rs 1.5/kWh, transmission cost till the grid ends @ Rs.0.45/kWhr and cost of extending the grid @ Rs.5.5/kWh, if 11 kV line is extended to 15 km with a load factor not more than 20%. The total levelised cost then works out to be Rs 7.50/kWhr. This analysis was supplemented with the sensitivity of assumptions made by estimating the cost of extension of the grid. In this scenario, in rural areas, the 1 MW dish is not only environmentally beneficial and efficient but also a commercially viable option

The fiscal incentives required to make solar thermal generation competitive were also outlined. He said that there is no need of incentives if 1 MW dish was replacing grid electricity extension. Otherwise, 30% subsidy would make solar option equivalent with a decentralized diesel generator. For hybrid option, '25% solar + 75% natural gas' generation will be competitive with natural gas combined cycle power cost if purchase price was raised from Rs 3.00 to Rs 7.00. Similar conclusion holds well for a solar chimney also. The assumptions were: 100% depreciation, 100% tax holiday for 5 years and 30% tax holiday for next 5 years and, 75% loan with 8.3% interest rates from IREDA with 2 year's moratorium and 8 years repayment.

Mr. U Goretzki, Vice President, India Regional Department, KfW presented the aid-financiers perspective on solar thermal electricity generation. He said that the financiers wanted to have a hedging instrument against projects of conventional power generation and renewable energy is important to avoid adverse environmental effects and that is the reason why KfW was interested in it. Then he gave a brief history and his views on Mathania Project. He informed about the feasibility study carried out of by KfW , on request of Government of India in 1990, on the generation cost of solar thermal plant and it was calculated to be about Rs 9/kWh at that time. Consequently KfW refrained from following up the project as commercial perspective with a reasonable amount of subsidy was not available. He also pointed out that either the technology should become more efficient or capital cost should come down sufficiently. After environmental considerations gained importance, in 1995, World Bank started discussion with Rajasthan Government on power sector reforms. Then KfW carried out another feasibility report which looked at various options and concluded that hybrid power plant with a combined cycle (natural gas) would be most favourable option. Hybrid option is advantageous in substantial reduction in initial cost related to sensible heat conversion to electricity. Also, the thermal input at lower temperature from solar generation can be advantageously utilized in hybrid plant for better efficiency. In case of hybrid power plants, obviously power will be available during non-sunshine hours also.

The purpose of such hybrid plants was to replace conventional fuels by solar energy and thus there is natural tie-off between solar contribution and efficiency. In Mathania Project the combined cycle was selected as reference technology for hybrid plant because it has lower cooling water requirements than Rankine Cycle. Also, it has higher cycle efficiency and lower CO_2 emissions per unit power generated. This is more in line with call of reduction in CO_2 emission and suitable to be combined with solar.

He also mentioned about the proposal for feasibility study of installing solar plants besides the existing combined cycle power plants of NTPC But NTPC's point of view was that the risk of adding solar plant to existing power plant is too high to justify such ventures. He said that there is great potential in India for such technology and Mathania plant is to demonstrate this possibility and convince the private power producers that the risk of such solution is bearable. The economics of such projects like Mathania showed following basic principles:

- The project should be implemented in sound sectorial environment in a way that ensures a commercial viability.
- The project should be setup in a way that is best suited to bring in use, expertise of building and operating of solar power plants.
- It should be looked at as a reference case that can be replicated in India.

He also suggested that the role of government should be only to set up a framework and it should not be an implementing agency. Finally, he summarized that the KfW has interest in further financing solar thermal plants in India and it believes that India is well placed geographically to use solar energy. The political situation for promotion of renewable energy technologies is also one of the best available in the world.

The perspective of a private entrepreneur was presented by ***Mr. C.M. Jain, President, Power & Energy Consultants***. He said that as there were no funds available, even for small solar thermal power projects, people are not coming forward. And everybody is thinking that till Mathania Power Project is completed nothing can be done in this field. He mentioned about the tenders by MNES in 1993-94 to install 10 MW power project, at that time number of private entrepreneurs were interested but not a single project has materialized, he cited the non-availability of soft loans and subsidy as the reasons

The cost of generation by solar thermal route is quite high and no private power producer will invest his money in a project where rate of return on equity is very low. The technology will be successful only if a development bank or government provides soft loans with a low interest rate and longer repayment period. He also put forward the fact that private entrepreneur is not interested in levelised cost which means that putting money now and getting benefit after 10-15 years.

He showed that not only cost goes down at higher capacities but the efficiency of steam turbine also increases. The results of calculations with 80% loan, 2.5% interest rate, 5 year's moratoriums and 15 years repayment shows that cost of energy generated for dish system is Rs 3.42/kWhr for 10 MW; Rs 2 26/kWh for 30 MW and; Rs 1.87/kWh for 100 MW capacities. However such incentives are not available so another calculation was presented to show that at what interest rates the solar thermal power plants will become feasible. The results were 10% interest rate for 100 MW generation capacity without a subsidy, 5% interest rate for 30 MW generation capacity with no subsidy, 2 5% interest rate for 10 MW generation capacity with no subsidy.

He concluded with the following recommendations to commercialize the solar thermal technology:

- Low cost funds should be made available
- Loans with 5 years moratorium, 15 years repayment
- Customs duty on materials and equipments should be nil.
- Supplies to STP plant should be treated as deemed export as was done for conventional power plants.
- Financial support to private entrepreneurs for pre-feasibility and detailed project reports.
- To encourage the participation of private entrepreneurs, the government should set up some demonstration plants, up to 10 MW capacity, with different technologies and at best locations. Then, in next 2 years it can be decided as to which technology is most appropriate.
- The component manufacturing should also start in India, then only private participation will be possible.

The views of private entrepreneurs were also presented by ***Mr. C.M. Trivedi, Managing Director, Solar Power Corporation*** He said that for any concentrating collector. the basic components required are: reflectors, selective coating, tracking system and, controls These components are already developed in western countries and in India we are still trying to develop it in a decentralized manner. For commercialization of concentrator technology in India, the indigenous development and production of these components are required. But the bottleneck is that there is no demand or market. This is indicated by the facts that around 1980's, there were 25-30 manufacturers in this field, while as on today only 3-5 are remaining in USA.

He also said that unless and until the solar thermal electricity generation is combined with conventional power generation, this technology will not be viable. The difference between conventional and solar thermal technologies is only the concentrators part, rest of the system being common for both types of systems. He stressed that MNES and IREDA should have a very precise policy for research and development. He suggested that in each state, the government should have 5-10 solar thermal plants, particularly for high temperature steam generation which is first step toward power generation. This experience of installations of such systems will help us to install solar thermal electrical generation. He also asked for liberal funding in initial stages.

Ms. Maria Kunder, Accounts Manager, TFL (Tata Finance Ltd.) talked about the renewable energy financing division of TFL, mentioning that TFL was the only non-banking financing company with separate division for renewable energy financing. At present, TFL has been financing scheme for solar water heating systems and solar photovoltaic systems. Some systems financed by TFL were shown. She said that once convinced about profitability of solar thermal electricity generation, TFL will be able to offer finance to such systems also.

In his concluding remarks, Dr. B.S.K. Naidu said that all the presentations were revolved about the point that low cost funds were the only requirements for promotion of costlier renewable energy technologies. He further said that what should scare the world community is not the environmental risk but the limitedness of fossil fuels. By present rate of consumption, by 2050 we would have used all our oil and gas resources and 50% of coal and nuclear sources. Again, the rate of consumption is also not constant but ever increasing so at that time we would have consumed almost all fossil fuels. This should be the main argument for encouraging the renewable technologies and not the environmental costs.

Another important fact enumerated by Dr. Naidu was that renewable energy sources are highly intermittent and seasonal so it becomes all the more necessary to plan for systems where renewables will give base load and conventional fuels will meet the peaking load. Furthermore, as renewable energy is energy for future, the government got to support it at any cost.

Panel Discussion

Chairperson :Dr. E.V.R. Sastry, Advisor, MNES

Panelists:

Dr. E.V.R. Sastry, Advisor, MNES
Dr. V.V.N. Kishore, Senior Fellow, TERI
Mr. Anthony Derrick, Director, ITP
Prof Steve Keneff, ANU

Mr. Anthony Derrick gave the brief summary of the presentations made. Dr. Shastry invited Prof. Keneff to give his views on the potential for solar thermal electricity generation in India and which are promising technologies.

Prof. Kaneff said that village level is most obvious starting point, and in this case, the generation capacity required is between 50 and 100 kW. The system is required to be modular, expandable and economical. For the grid connected systems, the cost can be reduced by economy of scale in manufacturing. Another suggestion from Prof Keneff was that for a cluster of villages in 20-30 km range, it will be affordable to have small generation system for each village without any transmission, and a team to maintain all the systems. It will be attractive cost-wise. He also suggested the possibility of thermochemical conversion at the receiver of a solar concentrator. He said that there was enormous scope in India, of economy of scale as there were 85000 villages without electricity.

Dr. V.V.N. Kishore started the discussion with the most relevant questions, which were, (1) technology development and, (2) funding for that. He opined that in the last 10 years, there was not much done toward technology development (except development of a solar pond), especially in the field of solar concentrators He said that no down to earth or ground projects in solar thermal technology were carried out Similarly, the renewable energy has neither a consistent policy nor the institutions like BAR or IRO working solely in the solar field with R&D programs, taking it logically to technology development and finally to commercialization. He suggested that along with Mathania Project, MNES should start a program so that indigenous capacity,to produce and absorb these technologies, so that after 10 years the country could have 100 MW to 1000 MW capacity power plants He urged to have a fixed R&D policy with long term objectives

Dr. E.V.R. Sastry gave brief information about some projects funded by MNES in past for technology development and there were several developments worldwide since then He said that the one of the objectives of this workshop was to decide what can be done in this area. Agreeing with views of Dr. Kishore, he said that there was a need to develop the technology and have indigenous production facility

During the discussions, the idea of having small scale projects to try out new ideas and designs was also explored and Dr. Sastry informed that after finalization of ninth five-year Plan, MNES would start a technology development plan. Based on its recommendations, MNES will start supporting fully some specific projects.

Mr. N.S. Prasad said that in the past some private institutions were also involved in the technology development but could not continue due to unavailability of a market Something has to be done to support and push the market. Reacting to this, Dr. Sastry said that while R&D is definitely the responsibility of government with some amount of capacity building, there were limitations in developing the market only from government side. The government can only provide fiscal incentives but the power plants need to be operated in commercially viable environment.

When asked about means of cost reduction, Prof Kannef mentioned the possibilities of cost reduction as (1) through economy of scale and, (2) lower production cost when manufactured in India (reduction up to 40-60% is possible when compared with costs of production in Australia). There can be further reduction of cost due to improvement in technology. He also mentioned the possibility in reducing cost by system optimization.

Mr S P Ranade, MITCON, requested that from the proposed technology development fund some funds should be made available to engineering colleges and institutions.

Dr. Sastry concluded that in present scenario, solar thermal power generation route could not be ignored, particularly in Indian context because India had limited fossil resources and needed power. The project report on 'Solar thermal electricity generation for developing countries' will receive a close attention in MNES and IREDA. These inputs will be used to develop appropriate technologies. He also mentioned of the possibility of credit line coming for solar thermal area.

At the end of the workshop, the Vote of thanks was proposed by *Mr. Amit Kumar, Fellow, TERI.*

Table A7.1: List of participants

S.No.	Name	Organization/Place
1.	Peter Raftery	IT Power Ltd
2.	S.P. Sharma	Energen International
3.	Anthony Derrick	IT Power Ltd
4.	Uday Singh Gautum	Vijayawada
5.	Shrikant Pittie	Pittie Renewable Energy Systems, Pune
6.	Jens Rosebrock	KfW
7.	Ernst Helmut	KfW
8.	R.S. Sharma	MNES
9.	C.M. Trivedi	Solar Power Corp.
10.	S.V. Srivastava	PEC
11.	Kavita Sinha	USAID
12.	S.P. Ranade	MITCON, Pune
13.	K. Ganesan	Rajapalayam Mills
14.	Thor Ramstetter	Fichtner
15.	Pramod Kulkarni	CEC
16.	A.K. Ghosh	BHEL
17.	J.B.S. Girdhar	MNES
18.	Ahmar Raza	MNES
19.	S. Kaneff	ANU, Australia
20.	C.M. Jain	Power & Energy Consultants
21.	Francis M. Fernandez	ANERT, Trivandrum
22.	K. Premkumar	ANERT, Trivandrum
23.	Fronk Wheeler	SfA, Australia
24.	Dr R.K. Bhogra	BHEL
25.	G.V. Kumar	TDICI
26.	V.K. Laroia	Industrial Development Services, New Delhi
27.	K.B. Agrawal	Energen International
28.	Vinay Garg	Megapower Engineering
29.	D.P. Bhasin	Vice President, Vimokas Consultants, N.Delhi
30.	A.K. Singhal	MNES
31.	N. Bapeshwar Rao	NEPC-MICON
32.	Abhilakh Singh	IREDA
33.	A. Anantha	REC
34.	K. Kgaphole	CSIR
35.	C. Parasoram	IIT, Delhi
36.	V. Mari Rajan	IREDA
37.	W.H. Gerdes	Bechtel
38.	T.C. Tripathi	MNES
39.	T. Hart	IT Power, India
40.	Dr Nielkanth J. Shendge	Sun Dance Power Gain Engg Pvt. Ltd, Pune
41.	Brig. M.R. Narayanan	CEO and ED, Mallebles Applied Solar Energy Group, New Delhi
42.	Ashvini Kumar	MNES
43.	B.J. Pathak	Solar Power Corporation
44.	G.C. Seeling-Machmeth	EDRC
45.	April Allderdice	Grameen Shakti
46.	Dipal C. Barva	Grameen Shakti
47.	M.V.R. Reddy	
48.	Rohit Tandon	Energen International Ltd.
49.	P.S.S. Adaxxarte, Consultant	Sun Dance Engineering Pvt. Ltd.
50.	K.M. Bhandari, Manager	Rajasthan Financial Corporation, Jaipur
51.	M. Sudarsan	CPRI, Trivendrum
52.	A.K. Goel	REPSO, WI, New Delhi
53.	B. Parthan	IREDA
54.	B.V. Rao	IREDA
55.	V.N. BaldiaAdvisor	PEC

56.	Ved Mitra	SEC
57.	R.K. Vimal, Deputy Manager	IREDA
58.	Lolit Gunaratne	Energy Forum, Sri Lanka
59.	Sanjeevani M.	Energy Forum, Sri Lanka
60.	Sanjeev Madan	Executive Engineer, M.P.Urza Vikas Nigam Indore
61.	J.C. Bonda	EPIA, Brussels
62.	Narendra Siwan	MNES
63.	D. Srinivas for Mr Sreedharan	NFL, Hyderabad
64.	K.C. Jaju	PEC
65.	A.K. Sharma	Deptt. of Electronics Engineering IT, B H.U., Varanasi
66.	Ms Kamalrukh J. Baria	Tata Finance Ltd.
67.	Mrs Maria Kunder	Tata Finance Ltd.
68.	Mr Naresh Kaushal	DSIDC, Delhi
69.	Mandava Srinivas	Electrical Research and Development Association
70.	Narendra Singh Rana	New Delhi
71.	P. Mahendra	New Delhi
72.	B.K. Mahendra	Chiragh Enclave New Delhi - 110 048
73.	Dilawar Singh	CASE, Australia
74.	G.R. Bhatti	WECS, Nepal
75.	N D Kaushik	IIT, Delhi
76.	Ajit Gupta	MNES
77.	EVR Sastry	MNES
78.	U Goretzki	KfW
79.	Vivek Bihani	TDICI, New Delhi
80.	BSK Naidu	IREDA
81.	Prof. Akio Suzuki	Tokyo A&T University, Japan